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TRANSACTIONS

OF THE

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SESSIONS

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TRANSACTIONS

OF THE

EDINBURGH GEOLOGICAL SOCIETY.

SESSION 1880–81.

I.—*Obituary Notice of Mr George Lyon.* By RALPH RICHARDSON, F.R.S.E., *Vice-President.*

(Read 4th November 1880.)

In Mr George Lyon our Society lost its oldest Member. He contributed to the commencement of the first volume of our Society's "Transactions" (1867) an historical sketch of the origin of our Society, which, he said, "was established in 1834 by a few individuals who met in the class-room of the late Mr Alexander Rose, Lecturer on Geology and Mineralogy, No. 1 Drummond Street." "At this period," he adds, "geology had made little progress in Scotland. The facts known were scarcely sufficiently numerous or important to take hold of or interest the public mind." Mr John Castle, followed by Mr Rose, were our Society's first Presidents, whilst Mr Lyon was Vice-President, until in 1862 he became President of our Society. Mr Lyon will, however, be best known as Treasurer of the Society, an office which he long and worthily held. In my capacity as Secretary I had frequently occasion to call at George Heriot's Trust office, Royal Exchange (where Mr Lyon was Cashier), and consult the Treasurer. I never knew a more pleasant or more genial counsellor. Withal, he was an excellent man of business, and kept a tight hand on our Society's always slender exchequer. He had also a thorough knowledge of our local geology, as is shown by such a paper as that on the "Trap Dykes of Edinburgh and Neighbourhood" in the first volume of our "Transactions," p. 325. In every relation of life Mr Lyon was honoured and esteemed. We shall miss his big brawny form, his cheerful face, and his ready joke at our Society's meetings. He died in Edinburgh on 17th September last, in the seventieth year of his age, having won respect from all who came in contact with him, and having by his probity and integrity well exemplified the truth, that

"An honest man's the noblest work of God."

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II.—*Notice of the Surface Geology of the Estuary of the Forth round Borrowstounness.* By HENRY MOUBRAY CADELL. (With three Plates.)

(Read 18th November and 16th December 1880.)

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I. PREGLACIAL PERIOD.

Buried River Channels.—Any respectable chart of the Firth of Forth shows a nearly semicircular bay extending for about three miles along the north shore opposite Borrowstounness, from the rocky promontory of Crombie on the east, to the quaint old royal burgh of Culross on the west. The ruinous pile of walls and chimneys—the remnants of the old coal and salt works of Preston Island—which rises picturesquely like some old fortress in the centre of the bay, is built on the north end of a low reef of rocks which stretches away into the Firth in a south-westerly direction, but at no point approaches within three quarters of a mile of the shore. A flat expanse of gray mud, dotted with patches of gravel and black boulders, sweeps round the bay at low tide, forming a deep "loop" in the broad belt of alluvium which fringes the shores of the estuary.

This bay, with its rocky islet, presents many features of interest to the student of denudation, and raises many a curious question. How, for example, does it happen that it is the only indentation of its kind on the north shore of the firth? and why it is that not a trace of rock is to be seen protruding through the flat zone of sleech which stretches round the bay between the rocky islet and the equally rugged shore? The fact that this island—unlike all the others in the firth—is composed not of greenstone but of bedded sandstone, which is not nearly so well fitted to withstand the action of the denuding agents, would seem

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to add one more to the list of problems to be solved, and we shall now proceed to examine how a satisfactory explanation of these phenomena can be arrived at.

Like all the other hollows in the coast line, this bay is not the result of any subterranean movement of the earth's "crust," but has been scooped out by one or other of the great denudants, to whose action every feature in the scenery and outline of our country is due.

The only two denudants at all adequate to this work are (1) Land Ice and (2) Water.

1. Land Ice usually occurs as a denuding agent in the form of glaciers, or ice-sheets, which are merely enormously extended glaciers. When a glacier moves down a valley it catches up pieces of the harder rocks over which it flows, and with them it grooves, grinds, and polishes the rocks forming the bottom and sides of its course, and, as Professor Ramsay has clearly shown, it has a decided tendency to scoop out the rocks below into the form of a deep hollow which usually becomes converted into a lake basin after the disappearance of the ice. During the last glacial epoch, or Great Ice Age as we are accustomed to call it, there is abundant evidence to show that the Firth of Forth at one period brimmed with ice, which finally, on the increase of the cold, swelled to an ice-sheet nearly 3000 feet in thickness which flowed off the east coast of Scotland, and after over-riding, grooving, and polishing in its course hill and dale alike, crept eastwards into the North Sea, where the northern portion joined the vast Scandinavian ice-sheet, and with it swept round the north of Scotland to break up into bergs beyond the Outer Hebrides. When the climate began to ameliorate the ice-sheet decreased in size, and each of its feeders again became a separate glacier. On the continuance of the warmer seasons the glaciers constantly dwindled down, till, having shrunk back into their respective glens, they finally disappeared altogether, leaving the rocks grooved and polished as we now find them.

If we consider the action of the ice during any of these phases in its cycle of operations and apply it to the case in hand, it is obvious (1) that the bay could not have been eroded by a passing glacier flowing off the land, because there is not the smallest evidence of such a glacier ever having existed, and because the form of the ground is flat and not adapted to the support of such a glacier; (2) that the bay could not have been hollowed out during the passage of the great ice-sheet, for the whole evidence, as given by the directions of the glacial striæ on the neighbouring rocks, shows that it flowed nearly due eastwards or slightly south of east, across the country, without respecting any minor features on its surface; its action was, moreover, a planing rather than a gouging one, and by no means adapted to the task of

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scooping out a crescent-shaped hollow like Torry Bay, and at the same time leaving a mass of rock sticking up in the centre; (3) that the smaller glaciers which flowed down the valley of the Forth both before and after the period of maximum glaciation were equally incapable of producing such results, because, in order to hollow out such a bay, the glacier would require first to assume extremely serpentine dimensions, and then to turn aside from its course, sweep up over the rocks, and after performing an admirable wheel to the right about, return to its original course, which is evidently absurd.

It is needless further to multiply cases to show that the bay was not hollowed out by any form of ice. No notice has been taken of the eroding action which icebergs were at one time supposed to possess. Dr Croll has admirably shown their utter inadequacy to striate the sea-bottom ("Climate and Time," p. 272), and the belief that they have ever had much influence in connection with the phenomena of the drift has been pretty generally abandoned ("Prehistoric Europe," p. 175; "Great Ice Age," 2d ed., p. 58).

2. Water, the second great denudant, wears down a shore-line principally by the operation of waves and currents, whose action has been aptly compared by Dr J. Geikie to that of a huge horizontal saw, carving out the cliffs into bays and promontories according to the respective hardnesses of the rocks of which they are composed. Torry Bay is, however, exposed to nothing but the gentle wash of the muddy currents of the Firth of Forth, which is here about three miles wide, and is well protected from stormy seas, being far removed from the wild billows of the German Ocean. But supposing it could, by any possibility, become exposed to the action of these marine grinders, it is evidently absurd to imagine that they would daintily carve out a semicircular hollow in the rocks of the shore, leaving untouched a skerry of the same rock right in front of the bay, which in all ordinary cases, instead of being left, would be the first to be demolished.

There remains but one other denudant at all capable of helping out the solution of our problems, which we shall now proceed to consider.

In an interesting and valuable paper read by Dr Croll before the Edinburgh Geological Society ("Transactions," vol. i. p. 330), and subsequently published in a chapter of his magnificent work "Climate and Time" (p. 467), he describes a buried river channel which approximately follows the course of the Carron and Bonny waters, entering the present estuary of the Forth at Grangemouth. This ancient Carron, he ascertained, flowed in a channel cut out of the solid rock in the form of a deep gorge whose bottom was found to be upwards of 45 fathoms below the

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present surface. The hollow, which could be traced all the way from Grangemouth to Kilsyth, was found by boring and mining operations to be filled with beds of sand, till, and gravel, which had been chiefly deposited during the successive glacial and interglacial periods of the Great Ice Age.

The discovery of this preglacial river channel was interesting in many respects. It proved, for example, that the river system before the advent of the Ice Age at least partially corresponded with that which now exists; it proved also that the land stood several hundreds of feet higher then in relation to the sea than it does now. It is thus imperative that there must be a buried channel somewhere under the present bed of the Forth, which received as tributaries the ancient Carron and many other smaller streams. Mr Milne-Home, in his "Estuary of the Forth" (p. 98), has described a deep hollow which exists in the rocks below the drift-beds at Causewayhead near Stirling, where the thickness of superficial deposits, consisting of sand, mud, and clay, amounts to no less than 216 feet. This hollow I take to be part of the buried channel of the Forth, and I account for the bay of Low Valleyfield and Torry by supposing it to have been also cut out by that river, and thus to form the site of a "link" in its preglacial course.

If this hypothesis be correct, we should expect that the belt of mud between the shore and Preston Island overlies a deep trough, eroded, like the ones at Grangemouth and Stirling, out of the underlying rocks, and filled with similar materials. As the evidence given by the appearance at the surface, of the existence of such a hollow, is purely negative, and therefore unsatisfactory, we must have recourse to an examination of the locality by means of "borings" or mining operations of some kind, if we are to carry the point.

The village of Torry is situated a little to the east of the centre of the bay, and formerly supported a small pier where coal from the adjoining district was shipped. The north end of the pier rested on the rock, which, as stated above, forms the beach all round the eastern side of the bay (see accompanying Map). In a boring made in 1839 by my father, at the point of the pier, the following section was passed through :—

	ft.	ins.
Gravel and sand, ...	5	0
Clay and sand, ...	3	4½
Clay, brown and clean, ...	30	11
Blue boulder-clay with stones, . .	23	8½
	63	0

In another bore made more recently near the shore at Low

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Valleyfield, about the centre of the bay, and about 870 yards west of Torry pier, the depth to the rock was found to be 120 feet, the intervening space being filled with boulder-clay alone. In a third boring, made about 200 yards farther west, the following section was passed through:—

	ft.	ins.
Gravel and soil, ...	8	0
Blue boulder-clay, ...	38	6
Sand and gravel, ...	18	0
	64	6

These three bores, then, indicate a rapid sloping away of the rock surface towards the centre of the bay. No rock is visible on the shore at Low Valleyfield, but it is found at the surface a short distance landwards. Rocks are very conspicuous all along the west side of the bay opposite Culross, and we have therefore good reason to suppose that if the surface of the rock continues to dip away seawards, we should expect to find a deep hollow underlying the mud between the shore and the island. There is, however, direct evidence that such a deep hollow does actually exist, for the workings in the old pits on Preston Island were suddenly truncated towards the north by a wall of boulder-clay which cut off all the seams in that direction.* In a copy of a plan of these workings made in 1811 I find that the engine level, which is 46 fathoms, or 276 feet below the surface, is marked as running 270 yards north-north-east from the shaft and then terminating. Whether this is the point where the clay was struck is not indicated, but very probably it is, as the workings were abandoned about that year. If it is, then the rock surface must dip away northwards at a high angle.

The distance between Torry pier-head and Preston Island is about 50 chains, or five-eighths of a mile, but the pier itself is about a quarter of a mile long, so that the trough would be three-quarters of a mile wide along this cross section, which cuts the direction of the hollow at right angles. The distance from the island to the bores at Low Valleyfield is also about five-eighths of a mile, but as these bores are within the hollow, we must take its width here as about three quarters of a mile too. It must, however, have been a little narrower where it entered the bay, as the rocks there do approach within five-eighths of a mile. The mud between the island and the east side of the bay is as broad as it is opposite Torry. On the accompanying map the channel is sketched as about half a mile wide, because we do not know

* This hollow is referred to in my father's paper, "Trans. Geol. Soc. Edin.," vol. ii. p. 44.

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for certain how the rocks close to the island lie; the edge of the hollow may in reality be farther north than the appearances at the surface indicate.

My father tells me that an old native of the district, who died several years ago at an advanced age, related to him a tradition of a disaster which once occurred in the coal-pits of Crombie, which were worked about the beginning of last century. The miners had either unexpectedly reached the "surface" or come upon a bed of running sand in the submarine workings which burst in on them, spreading death and destruction on all sides. There can be little doubt that this tradition is quite in keeping with the facts I have just stated, as the workmen may have struck the preglacial channel, which was there not filled with till but with running sand.

In the bore at Low Valleyfield referred to above, the bed of gravel which was found under the till is probably a remnant of the detritus brought down by the preglacial Forth.

The borings made in 1870 for the proposed Forth Bridge, for whose details I have to thank Mr William Wyllie, show that the depth to the top of the boulder clay between Inch Garvie and the south shore nowhere exceeds 102 feet, the silt in the centre being only 65 feet thick, while at 600 yards from the south shore the boulder-clay is only 35 feet below high-water level. (See App. C.)

After leaving Torry Bay the old river then probably followed the course indicated on the map, passing round the south side of Bimar and out towards Scandinavia between Inch Garvie and the north shore.

It might be asked, Why did the ancient Forth take a bend away to the north at that particular place? This question can only be answered by more or less probable conjecture, and the explanation I venture to suggest is, that in preglacial times the greenstone promontory of Borrowstounness, which lies right opposite Preston Island, extended much further north than it does at present, and may, directly or indirectly, have here deflected the river to the left. There is no sign of any volcanic bed among the rocks of Preston Island, and in my former communication on the Borrowstounness greenstones, I said enough to show that the lowest of the central series of traps does not at all events run far out to sea, but there is no good reason for supposing that some of the upper and thicker volcanic beds have not at one time extended considerably farther northwards than they do at present. It is true the strata are thrown down towards the centre of the firth by a series of step-like faults, but it must be remembered that the preglacial land stood several hundreds of feet higher in relation to the sea than it does now, and that the features of the country were much

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sharper before the planing by the ice began. The hard trappean beds would stand out in bold escarpments, and might have formed a ridge of sufficient influence to cause the river, when it began to hollow out its rocky gorge, to desist from its original intention of moving on in a straight line and to turn aside in the way indicated.

I may add that Mr B. N. Peach, F.G.S., of H.M. Geol. Survey, who has recently surveyed the district round Culross, tells me that there is a small bed of greenstone behind Low Valleyfield which he thinks is contemporaneous, and which occupies the position of some of the highest of the Bo'ness volcanic beds. It may possibly be the tail of some straggler from the Bo'ness traps, and if it is, my conjecture as to the prolongation of the volcanic snout in preglacial times is strengthened, but I am inclined to think that if it be really contemporaneous it must rather be connected with some of the Fife volcanos which belong to the same horizon as those of Linlithgowshire.

The enormous denudation which took place during the glacial epoch would have the effect of grinding down the ridge and reducing the softer parts of it to the level of the surrounding country. The old river courses, with any patches of sand and gravel which might remain, would be speedily covered up by the till of the *moraine profonde* of the first glacier, and on the retreat of the ice their sites would be completely obliterated, so that the modern streams would require to begin anew the task of cutting out channels for themselves.

Mr J. Bennie of H.M. Geol. Survey has kindly supplied me with fuller information about the Grangemouth channel than Dr Croll gives in his paper. He has indicated the position of the trough which is shown on the accompanying map as ascertained by Dr Croll, and subsequently verified by himself. The channel between Heuck Pit and Towncroft is probably 700 yards wide, but this line of section lies at a considerable angle with the direction of the trough, so that it may not in reality exceed 400 yards in width.

Practical Application.—An accurate knowledge of the geological and geographical relations of the ancient river system of our country, although of high scientific value, also admits of an application which ought to interest the so-called "practical" men of the day. The desirability of having railway communication between the north and south shores of the firth has long been felt, and as the various attempts which have been made to effect the transit by means of a bridge have hitherto proved unsuccessful, the alternative plan of tunnelling has recently been proposed. The foregoing considerations will, however, show that the project is beset with considerable geological difficulties, for unless the tunnel is driven at least 50 fathoms (probably nearer 60 or 70) below the present sur-

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face, it will be impossible to escape striking the old river channel. If the channel were filled with boulder clay there would not be so much danger, but the probabilities are that it is filled with running sand, mud, and gravel, with some of the "red clay" to be described below,* and if a bed of such a nature was tapped at a depth of say 200 feet at a pressure of 150 lbs. per square inch, the results, if not actually disastrous, might at least be personally inconvenient to the parties concerned. I understand the projected tunnel is proposed to cross between Hound Point and Donibristle, about a mile below Queensferry. The depth to the surface of the *mud* at the north ferry is 40 fathoms, and it is next to impossible that a mile further east there can be any till at 200 feet where the water is only 100 feet deep. The thickness of silt between Blackness and Queensferry is enormous. Mr T. Wyllie (I regret to have now to say *the late* Mr Wyllie), under whose charge the borings for the proposed bridge of 1865 were conducted, told me that he once pushed the rods down into the mud 27 fathoms at one time without getting to the bottom of it, and taking various circumstances connected with the recent history of the estuary into consideration, it seems highly improbable that the rise in the bottom of the channel below Queensferry can be due to any other cause than a heaping up of loose materials where the current which has transported them is less powerful.

Enterprise, in whatever direction, always meets with my hearty approval, and in offering these remarks it is far from my intention to appear hostile to the scheme. My object is simply to indicate some of the difficulties which may reasonably be expected, so that unnecessary trouble and expense may be spared which would otherwise be incurred if the work was gone about blindly, as is too often found to be the case in such undertakings.

II. Glacial Period.

1. *Roches moutonnées and Glacial Striæ.*—As there is such a thick covering of drift over the district round Bo'ness, very few glaciated rock surfaces are to be seen. I once caught a glimpse of some ice marks on the whinstone of Bell's Knowes Quarry, but lost the opportunity of measuring their direction, and now that part of the rock is all converted into concrete, so that there is little chance of regaining it. The western face of the greenstone island of Du Craig is well polished, and the basalt on which Blackness Castle stands also bears evidence of intense glaciation. The rock surface slopes W. 35° N. and the striæ run up it in a slanting direction which varies from E. 5° N. to E. 5° S. Their tracks are perfectly distinct and not the least impaired by the waves of centuries. The surface of the diabase

* Since reading this paper I have communicated with Dr Jas. Geikie, who tells me he has informed the engineer of these obstacles to the scheme.

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of Bowden Quarry, about 5 miles south from Bo'ness, is also a characteristic *roche moutonnée.* The striations there run almost due E. or E. 3° S.

2. *Till or Boulder-Clay.*—This characteristically glacial deposit forms the almost universal rock covering, both over the land surface and the sea-bottom. It occurs, as we have seen, upwards of 270 feet below sea-level, and mounts as high as the 500 feet contour, being found spread over the sides and shoulders of Bonnytoun Hill. It usually retains the colour of the rock it overlies: thus it is dark blue or gray along the shore where the outcrops of shales predominate, while it is generally brown and sandy farther inland where greenstone and sandstone form the chief surface rocks. It has occasionally been struck in the submarine workings between Bo'ness and Bridgeness. On one occasion the ironstone and parrot seam was excavated for a distance of 50 yards under a roof of boulder clay and at a depth of 137 feet below sea-level. At one part of the working a boulder of hard brown sandstone of a kind not found at any part of the district, rolled out of a hollow in which it had lain snugly ensconced since the beginning of the Ice Age. When brought to the surface it was found to be beautifully glaciated on one side, the striæ resembling the flutings on the shell of the common clam. It is scratched but not distinctly glaciated on the other side, and seems to have been worn away and partially rounded, then turned over and grated down in a different direction. It is in the form of a thick-set ellipsoid, and measures 2′ 10″ × 1′ 6″ × 1′, and is now preserved at Grange, where it may be examined by any glacialist visiting the district.

While driving a level in the "red coal" from No. 5 pit Bridgeness, the river bed was again struck in the beginning of April (1881). The rock covering was fortunately boulder clay in this case also. The miners came on it at a depth of 217 feet below mean sea-level and 200 yards beyond low-water mark, at a distance of about 430 yards north-west from the end of Bridgeness pier (see A on map).

It is impossible to form any estimate of the average thickness of the till at any part of the district, as it is so variable. Mr Wyllie has supplied me with the journal of a bore on the farm of Mannerston to the south of Blackness, where the surface, which he said was chiefly till, was found to be not less than 149 feet in depth. How it is that such an abnormal thickness of drift should exist here remains to be discovered.

The boulder-clay occasionally takes the form of "drums" as they are called in many parts of Scotland. The most conspicuous of these elongated mounds is that which crowns the high ground immediately above Bridgeness, and extends for about three quarters of a mile westward from Carriden to the hamlet of

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Graham's Dyke. Its highest point, which reaches almost up to the 200-feet contour, is situated nearly half a mile from the shore, and forms the site of the Drum farm. In the absence of natural sections it is impossible to determine the relative age of this ridge, but there can be little doubt that it belongs to one of the later periods of glaciation, probably to the period immediately preceding the last interglacial epoch to be noticed in the sequel.

The ground to the south of the Drum slopes gently away and flattens out into a stretch of fertile fields whose stiff soil is well adapted to the cultivation of wheat and beans. This area is considerably below the level of the steading, and is in fact the site of an old lake*—a fact endorsed by the names of places in the neighbourhood. Thus the two fields lying immediately to the south and south-west of the farm are named respectively the "Loch" and the "Little Loch," while the small hamlet at the east end of the "Loch" is named "Lochend." The lake—evidently formed by the moraine-like "drum" damming back any water which might accumulate from the high grounds to the south—has been drained chiefly by the Carriden Burn which takes its source near Lochend, and which has cut down its channel so that the imprisoned waters could escape eastward at a lower level.

The contents of the till will be considered later on.

3. *Evidences of Interglacial Periods.*—An interesting bed of gravel has recently been disclosed below the "tirring" of Bell's Knowes Quarry, which rests in a trough-like hollow eroded out of the soft bed between the upper and lower greenstones worked there. The accompanying sketch (Plate II.), which is roughly drawn to a scale of 8 feet = 1 inch, shows the gravel bed covering the bottom and right or west side of the hollow. The upper part of the gravel is very fine-grained passing into finely stratified and false-bedded sand, but towards the foot of the section all signs of stratification disappear; the stones grow larger, and in the bottom of the trough the gravel becomes mixed with boulders, the largest one I saw being over a foot in diameter. The whole is cut off and overlapped unconformably by a tumultuous mass of stiff brown till full of small stones.

At first sight this section has a decidedly preglacial aspect, but a closer examination soon convinced me that this could not be the case, as the gravel is composed of small pebbles of quartz, greywacké, schist, porphyrites, &c., which must have travelled a long distance from their parent rock. It is certain they could never have been transported thither by water, and hence we are forced to conclude that they must have been brought by ice, probably in the form of land ice. The larger

* The position of this "drum" and post-glacial lake is incidentally shown on sections Nos. 2 and 3 of my paper on the volcanic rocks of this district.—"Trans. Geol. Soc. Edin.," vol. iii. part iii. 1880.

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boulders were, however, apparently all composed of the dolerites such as occur plentifully in the neighbourhood. No organic remains were to be seen in the gravel.

This section then, points to a time when the extreme rigour of one of the earlier phases of the Ice Age had become mitigated, and the surface of the country, all covered by the till which the retreating glaciers had left, was the scene of rills and brooks, babbling over the clay and pebbles brought from the distant Ochils and Grampians. On the continuance of these mild and genial interglacial seasons the old till would to a great extent be gradually washed away, and the streams would begin to cut out channels for themselves in the underlying rock. The smaller stones and sand which they had separated from the ice-worn debris would be sorted into coarser and finer beds, where the current slackened in the minature glens, while the argillaceous portion would be carried off in a fine state of division to be deposited as mud in the distant sea. When the cold again advanced, the streams would dwindle down till they at last became frost-bound and dry. The mighty robe of ice would then come flowing down the valleys, pushing a tumbling mass of stones and mud before it, and choking up all hollows in its way. In our section the ice has first filled up the old water course with till, then grated along the surface of the rock like a hugh rasp, raking the angular lumps it had torn off over the top of the till, as if to blot out the marks of the channel even more completely, and indeed it has been successful to a very considerable degree, for the gravel and clay appear, when viewed in a particular direction, as if completely buried beneath the greenstone breccia thus produced.

In sinking No. 6 pit at low-water mark 150 yards east of Bridgeness pier, the boulder-clay which there rests on the rock was found to have a thickness of about 6 feet. The lower 5 feet consisted of a dark bluish gray tough and stony clay full of rounded and angular blocks of greenstone, sandstone, shale, limestone, greywacke, quartzrock, and ironstone. On the top of this blue till was found resting a bed of the same consistency, but totally different in colour and in the character of its contents. This overlying bed had a perfectly distinct dark chocolate pink hue, sharply contrasted to, and as sharply defined from the sable mass below. As far as I could ascertain, its contents seemed to be entirely made up of fragments of a quartz conglomerate in a coarse red sandy matrix, like that of the Old Red Sandstone. A beautiful boulder of this conglomerate, measuring 2′ × 1′ 6″ × 11″, was brought up from the bed. It is not thoroughly rounded, one side being sub-angular.*

* Also to be seen at Grange in company with its neighbour of the striated back.

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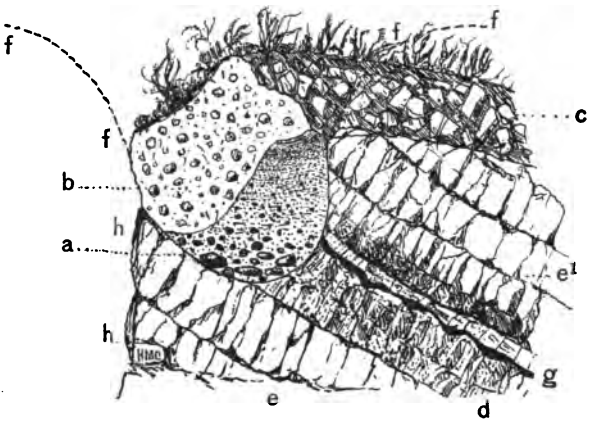
Section of Interglacial Stream Channel, at Bell's Knowes Quarry, Bo'ness.



a. Gravel bed with boulders at base.

b. Till overlying gravel.

c. Breccia of greenstone torn off e^1 by glacier.

e. Lower sheet of contemporaneous greenstone, with decomposed upper surface (d.)

e^1 Upper greenstone decomposed at base.

f f f f. Probable outline of stream channel before last glaciation.

g. Contorted carbonaceous bed overlaid by indurated sandstone.

hh. Face of east quarry.

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This bed of red clay, whose thickness varied from about 9 to 18 inches, appeared to be quite a lenticular patch, probably only a small remnant of a much more extensive deposit which has been almost all washed away by the furious rivers of the last interglacial epoch. It is not met with in any of the borings made along low-water mark eastwards from Bridgeness pier, with the exception of one put down close to the shaft which passed through 2 feet of red clay overlying the thin bed of sand and stones which there covered the rock. (See Appendix A.)

The question as to the origin of this upper clay is of interest, as the bed was evidently deposited in quite a different way from that in which the till was formed. The most reasonable explanation seems to me to be that propounded in the "Great Ice Age," (2d ed., p. 329–30,) where it is stated that "certain deposits of boulder-clay at low levels and in maritime districts were accumulated during the final recession of the ice in the last cold period." The level is quite low enough to permit of the bed being correlated with these deposits, for the clay was found about 95 feet below high-water mark, and the district is quite maritime enough too. I thus take this bed to be a relic of what Dr J. Geikie calls *boulder-clay* in opposition to *till*, and account for its existence here by supposing it to have been discharged over the front of some of the last glaciers during their final retreat to their mountain fastnesses, while the dark underlying stony clay may have been formed long before, as the *moraine profonde* beneath some of the earlier glaciers of the Ice Age. There may therefore be a vast interval, possibly comprising several glacial and several interglacial epochs, between the formation of these two clays. The relative positions of the till and boulder-clay are shown at *a* and *b*, Plate III.

I have only three cases to record in which interglacial periods are indicated by stratified beds intercalated with the till. They are as follows :—

Bore at Powfoulis House, opposite Kincardine.

	ft.	ins.
Surface and clay,	5	0
Sea mud and shells,	40	0
Sand, mud, and shells,	18	0
Sea mud,	14	0
Gravel and stones,	28	0
Red sandy clay,	17	0
Blue till,	10	0
Quicksand,	9	0
Blue till,	20	3
Depth to rock,	161	3

Bore at Dalderse (No. 1), near the Carron.

	ft.	ins.
Surface and clay,	4	0
Sea mud and sand,	18	0
Red mud and yellow clay,	43	0
Blue till,	16	0
Sea mud and quicksand,	73	0
Blue till,	3	0
Depth to rock,	157	0

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Bore at Manuel House, west of Linlithgow, S (*on Map*).

	ft.	ins.
Sand and gravel,	5	6
Blue till,	2	0
Sand and gravel,	6	6
Blue till,	3	9
Depth to rock,	17	9

4. *Last Interglacial Period.*—The till and boulder-clay, although usually overlaid by the glacial "red clay" to be described presently, is sometimes covered by a bed of sand or gravel which is a relic of the detritus brought down by the powerful rivers of the last interglacial period. In the line of borings made eastwards from the point of Bridgeness pier along low-water mark (Appendix A), this gravel bed was found separating the two glacial deposits, sometimes very clearly. Its thickness there is little over a fathom. In two of the borings to the rock at Bo'ness dock a bed of sand and stones, about 2 feet in thickness, was revealed occupying the same horizon (see Appendix D).

With the exception of these sections I have not met with any bed of a similar nature either at Blackness, Torry, Low Valleyfield, Powfoulis, or Grangemouth. In the last-mentioned locality, Dr Croll's list of bores (already referred to) shows the red clay resting on till in every instance. The Bridgeness borings are nearer the centre of the river than those at Bo'ness, and hence it is natural the old river gravels should be thicker there; and if borings were made still further seawards, this bed would in all probability be found both with greater thickness and greater persistency.

Its position is shown at *c* on the section Plate III.

5. "*Red Clay*" *of last Cold Period.*—This deposit forms a thoroughly well marked and characteristic horizon among the drift-beds of the estuary. It occurs in almost all the sections I have seen which have reached the till, with the exception of those at Queensferry, and although almost entirely devoid of organic remains, it is very far from being devoid of geological interest.

It is correlated by the Geological Survey with the beds belonging to the 100-feet raised beach, and so far as my observations go it does not occur at a higher level round any part of the coast.*

Its colour is more aptly described as red than brown, dark

* Mr Milne-Home incorrectly states at p. 27 of his "Estuary of the Forth," that this clay occurs at Blackness Tile Work at a height of 150 feet above sea-level. The clay pits are in reality situated between the 50 feet and 75 feet contours, no clay having been worked much above that height.

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pink would perhaps give a better idea of its hue, as it is coloured chiefly by the anhydrous peroxide of iron, which also gives its characteristic tint to the Old and New Red Sandstone rocks. In consistency it resembles lard, being often remarkably free from sand and stones. Lamination is, however, generally clearly visible, the laminæ being composed not of more or less sandy layers but of lighter and darker bands in the clay itself. When dry the clay shows no tendency to split along these planes. It is essentially composed of the flour of rocks, and is, in fact, "a true ice-formed mud carried from inland glaciers by streams and deposited in the quiet waters of the Firth." *

Organic materials of every description have usually been found to be eminently conspicuous by their absence from this deposit. Bones of a seal, supposed by Professor Turner to be *Pagomys fœtidus*, were found in it at Grangemouth. Fragments of shells, usually of an arctic type, are also occasionally found along with a few foraminifera, while at Camelon and Grangemouth remains of little Greenland floe rats have been exhumed from its unctuous folds. Such "finds" are, however, quite exceptional; the colour of the clay itself testifies to its freedom from organic remains, for it is well known that the decomposition of such bodies give rise to the disengagement of certain gases which abstract part of the oxygen from the red peroxide of iron and reduce it to the form of the green protoxide. This is why the overlying carse clay or silt, which (as its odour alone clearly testifies) is saturated with organic matters, is not red, but dark green or blue in colour.† In course of the operations at present in progress at the new dock, Bo'ness, the top of this clay has been well exposed. Mr F. Jopling, resident engineer at the works, who has kindly supplied me with much interesting information about the adjacent drift-beds, gave me part of a calcareous concretion which had been dug out of the surface of the red clay while the excavations for the south dock wall were being made. It was originally about a foot in length, and bore a rude resemblance to a stag's horn. Part of it, which was encrusted with small shells, I submitted to Mr David Robertson, F.G.S. Glasgow, who kindly examined it and found the organisms to be chiefly the young of *Cardium edule* (cockle), also *Tellina*, apparently *T. balthica* and *Hydrobia ulvæ*, none of which are characteristic arctic forms. The shell of a hazle nut which was also embedded in the mass rendered it still less arctic in appearance. This concretion, which is very like those found in the more recent clays, has probably found its way into the surface of the glacial mud after the climate had begun to ameliorate.

* Mem. Geol. Survey, to sheet 31, p. 52–3.

† The blueness is often due to the presence of vivianite, which is the phosphate of the protoxide of iron ($3FeO.PO_5+8HO$).

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Large boulders are rarely met with below the surface of this clay. None, so far as I know, have as yet been exhumed in this district.

6. *Boulder Bed overlying Red Clay.*—The dock excavations at Bo'ness have exposed a very interesting bed of boulders, many of them of large size, lying on the upper surface of this clay. Although hardly any of them showed traces of ice scratchings, they presented an appearance so like that of the stones in the till itself that I was led to suspect some definite relation must subsist between the two series. With a view to settle this point as precisely as possible, I visited the works several times, and had frequent opportunities of examining the different kinds of rock of which the boulders were composed. The smaller stones were gathered by the navvies into heaps preparatory to being broken up for concrete, and while thus exposed I managed to make a rough catalogue of the numbers of stones and percentages of the different kinds of rock in several of the heaps. The results of an examination of six heaps or assemblages of boulders are given in Table A.

In order to compare these results with the conclusions to be arrived at after a similar examination of the contents of the till itself, I went to the shore below Stacks farm (B on map), about 2½ miles east of Bo'ness, where that deposit is well exposed, and where the beach is covered with scratched stones which have been washed out of it by the waves. Two separate areas A and B, the former 36 and the latter 45 square yards in extent, were selected from parts of the beach where the till seemed best exposed. All boulders upwards of 3 inches in diameter were gathered into heaps and counted as accurately as possible, without of course any previous knowledge as to how the results would turn out. The results are tabulated in B on the opposite page.

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	Name of Rock.	A. Boulders on top of Red Clay.									B. Boulders in Till.				
		Heaps of Boulders in Dock.							Percentages.		Areas on Beach.			Percentages.	
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	Totals.	Rocks.	Formations.	A.	B.	Totals.	Rocks.	Formations.
Carboniferous.	Greenstone,	60	7	12	8	9	62	158	42·36	79·09	88	53	141	41·97	74·11
	Sandstone,	23	16	9	6	1	70	125	33·51		55	22	77	22·92	
	Limestone,	2	...	1	...	1	7	11	2·95		10	10	20	5·95	
	Ironstone,	1	...	...	...	...	...	1	0·27		6	5	11	3·27	
O.R.S.	Porphyrites and felstones,	6	4	...	1	2	10	23	6·17	9·65	22	15	37	11·01	13·09
	Red quartz conglomerate,	4	...	...	2	4	3	13	3·48		4	3	7	2·08	
Silurian.	Grits and greywackes,	3	1	...	4	3	9	20	5·36	10·99	14	9	23	6·85	12·21
	Schists and gneiss,	6	...	2	...	1	3	12	3·22		4	1	5	1·49	
	Quartzite,	6	...	1	...	...	2	9	2·41		7	6	13	3·87	
	Granite and syenite,	...	...	...	...	...	1	1	0·27		2	...	2	0·59	
	Totals,	111	28	25	21	21	167	373	100·0		212	124	336	100·00	

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From these tables it is obvious, in the first place, that the great majority of boulders in both cases consists of "greenstone," a general term comprising basalts, dolerites, and diabases, some of which have travelled from the neighbourhood of Stirling, but most have been broken off the adjacent rocks. That this is pre-eminently the case may be gathered from the fact that the sandy parts of the beach near the outcrop of the till are at places quite blackened by innumerable grains of magnetite (Fe_3O_4) which have been separated from the sand by the waves. This oxide of iron, which forms an essential constituent in basaltic rocks, is often found where volcanic rocks have been disintegrated,—as, for example, on the shore at North Berwick and Dalmeny, at both of which places extensive tracts of basalt form the coast line. In this case, however, the mineral has been separated from the greenstone boulders which cover the shore by the grinding action of the waves, as no tract of basalt of any importance occurs within reach of the sea at any part of the coast, Blackness Castle rock, which is about a mile further east, being excepted.

Next come the sandstones, which show a much greater disparity. This is what should be expected, for the ice-sheet travelled eastwards as we have seen, and would bring in a large proportion of sandstone boulders to the neighbourhood of Bo'ness from the non-volcanic millstone grit and Coal-measure rocks to the west, while it would carry east an equally large proportion of the greenstones of which the "ness" is composed. The percentages of limestone and ironstone are higher in the till, because beds of these rocks happen to crop near the place it was examined.

The percentages of greenstone are remarkably close in both cases, which should *not* be expected, but this circumstance can be readily explained from the fact that I inadvertently classed many of the more acid porphyrites and felstones found in the dock along with the greenstones, as a considerable proportion of them were too round to chip and too mud-bespattered to distinguish properly. If then, we add together the greenstones and porphyrites in each case, we get a percentage in the till of 52·98, and in the boulder bed of 48·53, which is probably nearer the correct relative proportions of Palæozoic volcanic and trappean rocks in the two localities. Bearing this fact in mind, let us next turn to what I have roughly enumerated as Old Red Sandstone in the tables. The percentages of Old Red Conglomerate which can be readily distinguished are close, as are also the metamorphosed Silurian rocks. The Carboniferous rocks, which show the greatest disparity, if treated in the same way as we treated the greenstones, give in table A 85·26 and in B 85·12, which is certainly a wonderfully close relation.

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The classification of the boulders according to their respective formations, although necessarily a very rough one, is quite accurate enough for our present purposes, and the total number examined (709) is large enough to insure against any very serious error in estimating their several relationships.

As regards size, it was only the medium-sized boulders in the dock which had been gathered into heaps. Heap No. 1 contained the largest number of small stones, which varied from 3 inches to 1½ feet in diameter, probably averaging about 9 inches; Nos. 2 and 3 were composed of larger stones, from 1 foot to 2½ feet in diameter; No. 4 is a list of large isolated boulders lying about where they had been disinterred. None were less than 2′ × 1½′ × 1½′, the largest being a subangular block of reddish gritty sandstone with large red quartzite or porphyrite pebbles which I take to be a piece of Old Red Sandstone conglomerate, measuring 4′ × 2½′ × 2′. Nos. 5 and 6 likewise include patches of recently uncovered isolated boulders not less than a foot in diameter. Mr Jopling informs me that by far the largest boulder which has been laid bare was a subangular block of sandstone measuring 6′ × 4′ × 5′, and that the next in size were of whinstone, many of them measuring about 3′ 10″ × 2′ × 3′. The sandstone boulders were usually found to be more angular than those of whinstone.

It is quite evident that these boulders could never have been brought here by water, for the following reasons:—

1*st*. A large percentage of them belong to the adjacent rocks, and have therefore scarcely been transported at all. The rest have mostly all travelled considerable distances, but the number of metamorphic rocks which have come from the distant Grampians is slightly in excess of the number of less ancient rocks which have travelled from the neighbourhood of Stirling and the Bridge of Allan—about half the distance. Had there been, however, a tremendous "wave of translation," such as the older geologists were wont to summon up from the "vasty deep," like a species of semi-omnipotent angel sent from Neptune to explain all otherwise unaccountable drift phenomena, it would have brought a much larger proportion of rocks from Stirling than from Callander, where the metamorphic rocks begin.

2*d*. The largest of them are of sandstone, and are more or less angular. If they had been rolled along by currents powerful enough to move them, the corners would soon have been knocked off, and they would in a short time have been ground down to the sand from which they were formed at first, especially as many of them were of very soft and friable sandstone.

3*d*. Currents of such intensity would also carry along

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tremendous quantities of small stones, sand, and gravel, but the gravel found along with the boulders on the top of the red clay is generally of very small importance, and is hardly to be seen at all at some parts of the bed.

All the facts of the case are totally at variance with such a hypothesis. The finely banded appearance of the clay, its remarkable freedom from stones and sand, and its uniform distribution and consistency, all these point to its having been deposited in perfectly tranquil water. It is, as we have already seen, distinctly arctic in character, and I think we have good reason to believe that the submarine portion of the deposit at least was laid down under such severe climatal conditions that the surface of the sea was coated all over with a thick crust of ice, under which the waveless water could precipitate its mud in perfect tranquility.

At the beginning of the last interglacial epoch the first showers would fall on a land all covered with scratched stones and till. A large part of the latter would be carried off under the action of ordinary subaërial denudation, and gradually most of the scratches would become obliterated as well. As the last cold period approached, all the loose materials on the margin of the glacial sea would probably become frozen hard and fast into an "ice-foot" such as fringes the shores of Greenland at present, and had in all likelihood existed in Scotland at earlier stages in the Ice Age.* Large fragments of rock detached by rain and frost from the neighbouring bluffs would also be caught up and frozen in along with the boulders on the shore; they would remain angular, and consist chiefly of greenstone and sandstone.

When the severity of the climate under which the red clay was deposited began to diminish, a general thaw would commence, and the ice-foot would become partially melted and broken up into larger and smaller cakes. Many of these ice-rafts would float off and drop their loads on to the surface of the red clay which then formed the sea-bottom, as they melted. It seems reasonable to suppose that the great majority of the stones discharged from the ice would be thrown down near the shore, and this is precisely what has taken place, for the boulders are far more numerous at the south or shore side of the dock, which is about 150 yards wide, than at the north side.

Mr Peach tells me he has observed beds of boulders in the brick clay (the upper portion of the red clay) at Valleyfield Tile Works and at the brick work near Clackmannan Railway Station. There may thus have been several breaks up of the

* Great Ice Age, 2d ed., p. 194.

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ice-foot ere this last cold period closed, but it is certain that none took place earlier than the one I have just described. It is quite possible, however, that these beds may have originated at the same time as the one of Bo'ness, the boulders having been dropped into shallower water by the melting ice immediately after being liberated from the shore.

The sea at this period stood about 100 feet higher than it does at present, and the accompanying sketch section (Plate III.), which shows the relative positions of the drift beds at Bo'ness as well as the 100-feet raised beach, also indicates the part of the shore which was probably covered by the ice-foot at the close of the glacial epoch.

The question naturally arises as to whether there were tides here during the deposition of the red clay. The evidences of extreme tranquillity in the water appear unquestionable, and hence we might perhaps not be inclined to find much fault with old Dr Fleming when, in his "Lithology of Edinburgh," he broaches the idea that the brick clay or "silt" of that district (which is the representative of the Bo'ness red clay) was deposited in a lake of some sort. Had there been tides and powerful currents, it may seem unlikely that they can have conduced to the tranquillization of the firth, and at first sight we might be inclined to think the ice-foot and ice covering would be constantly getting broken up so as to allow of debris being dropped into the water. These objections can, however, be removed by appealing to ascertained facts, for in the first place it is well known that the Greenland ice-floes which are formed along the shores every winter grind up and down against the face of the ice-foot which fringes the coast.* In this case the cold was more intense, and we have only to substitute a permanent cake of ice for the temporary ice-floes which may be supposed to slide or rather to grate up and down against the cliffy ice-foot like a huge and very irregular piston raised by hydraulic pressure inside an equally irregular open-topped cylinder of ice. The surface of the sea-bottom would thus be protected from any disturbance by stones being dropped in from ice-rafts floating above. In the second place, the quantity of fine silt forming in the estuary proves that strong currents as well as tides are not necessarily prejudicial to its deposition.

7. *Raised Beaches and Perched Blocks.*—After the ice had melted away to a considerable extent, the sea began to retreat, and the various pauses in the emergence of the land were marked by a series of raised beaches. They contain arctic shells at some parts of the country, and indicate a gradual rise of

* Great Ice Age, p. 55.

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temperature as the climate continued to approximate to that in which we live. The land rose till the bed of the German Ocean became converted into dry land, which was latterly covered with vast forests. Submergence and subsequent re-elevation once more ensued, and the low level raised beaches were formed ("Great Ice Age," p. 331).

The 100-feet raised beach is the only conspicuous relic of the glacial sea margin in the immediate neighbourhood of Bo'ness. Plate III. is a section drawn in a north-westerly direction past the east end of the town through this old terrace at one of its most characteristic points. Between the 25-feet and 100-feet contours the land rises rapidly up to the south and then slopes away in a shelving terrace to the 150-feet contour. In a series of excavations recently made along this terrace, the soil was found to rest on about 8 feet of sand and gravel (*g*), which in turn rested on a bed of fine brown clay, probably the highest portion of the red clay. Towards the 150 feet contour, where the land again becomes much steeper, beds of sand are to be seen sloping up against the rock, which clearly indicate that a beach existed there at one period. In this steep bank, formed by a greenstone escarpment, a bed of mussels, oysters, and wilks of the ordinary species was lately disclosed a short distance below the 200-feet contour. The shells are perfectly clean, and look as if they had been laid there by the waves, but they are not associated with any stratified beds, and rest immediately on the talus of angular pieces of whinstone from the adjacent cliff. They appear, however, to be far too clean and unmixed with foreign materials to be classed with the "kitchen midden" beds so well exposed to the west of Bo'ness.

The 40–50-feet raised beach is distinctly seen between Bridgeness and Blackness, but I have never been able to discover any very distinct marks of a 20-feet terrace in the immediate neighbourhood such as Mr Milne-Home has noted at p. 104 of his "Estuary of the Forth," as occurring in this neighbourhood.

A few feet above high-water level, a good section has been uncovered to the east of Bridgeness, which shows the old beach to be composed almost entirely of recent shells, the vast majority being cockles in a very good state of preservation. The principal species in the bed are *Cardium edule, C. echinatum; Buccinum undatum, Purpura lapillis, Mactra subtruncata, Turritella communis, Littorina littorea.*

Perched Blocks, &c.—After the last glacier had retired, many boulders were left sticking into the sides of its course or scattered over the land it had recently left. The best example of a true "perched block" I have observed occurs in the steep

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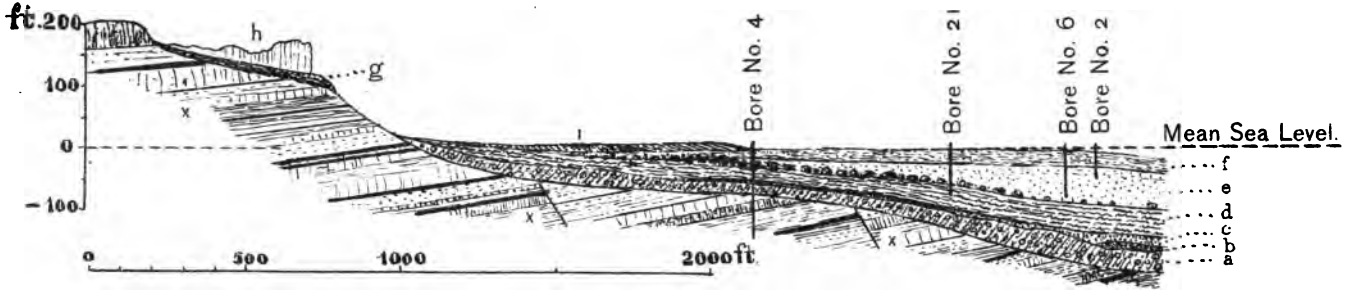
Section of Drift Beds at Bo'ness.



x. x. x. Carboniferous rocks.

1. Recent littoral accumulations.

h. Probable position of last Ice-Foot.

g. Gravel bed overlying clay of 100 ft. Raised Beach.

f.	Bluish-green silt and carse clay	= recent estuary, mild climate.
e.	Sand and gravel with boulders at base	= large rivers and melting ice.
d.	Red Clay without stones or fossils	= distant glaciers and frozen seas.
c.	Sand and gravel, irregular bed	= large rivers and melting ice.
b.	Red Boulder-clay in patches	= later large glaciers retiring.
a.	Dark blue tough and stony Till	= earlier large glaciers advancing.

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bank immediately below the 100-feet raised beach to the east of Bo'ness, where a boulder of porphyrite about 2 feet in length is seen jammed into the face of the soft rock with its longer axis pointing east and west. It is well striated in that direction, and has evidently been forced into its present position, and there polished and grooved by one of the last glaciers which filled the firth. Another case is seen to the east of Bridgeness, where an oblong and well rounded boulder of greenstone measuring $7' \times 5' \times 3'$ rests, or rather hangs in an extremely precarious position from the side of the steep bank forming the old shore line at a height of about 75 feet above sea-level. It seems to lie in a hollow of the rock in this case also. Several other "erratics" occur along the shore to the east of Bridgeness, among which greenstone predominates both in point of size and in point of numbers.

The retiring glaciers also left behind large quantities of sand and gravel, formed by some rather mysterious process into "kames," or hummocky and often straggling mounds whose contents are usually found to be false-bedded, and sometimes faulted and crumpled to a most extraordinary degree. Many of these kames are to be seen in the neighbourhood of Linlithgow, where several good sections are at present exposed, both at the east and the west ends of the town (see Appendix E, 4 and 5).

III. Post-Glacial and Recent Period.

1. *Rise of Land.*—The belief which for a time obtained among geologists that the 25-feet raised beach had been elevated since the Roman occupation of Britain has now been abandoned. The discovery in 1868 of a splendid Roman legionary tablet at Bridgeness, besides being of interest to the antiquarian, as marking the spot where the famous wall of Antoninus (Graham's Dyke) terminated, was also in some degree interesting to the geologist from its bearing on the question as to the rise of land during the last eighteen centuries.

Mr Milne Home visited the spot in 1872, and read a paper before the Royal Society of Edinburgh* setting forth the results of his investigations, in which he adduced certain "facts" to prove that no rise of land had taken place since the tablet was made. The following are Mr Milne Home's three chief conclusions:—1*st.* As the stone was *found* only 19 feet above sea-level, it *must* have been covered by 6 feet of water at every tide had the land stood 25 feet lower than at present.

2*d.* "... the neck of land which joins the ness or knoll to the

* Trans., vol. xxvii. pp. 39–50.

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mainland, being only 23 feet above high water, must have been submerged and exposed, so that any wall or rampart on that neck would soon also have succumbed to the waves."

3d. "Then there is the old building at the point of the Ness, which, if Roman (as it appears to be), must have been *at all times* under water, even at the lowest tide, were Professor Geikie's theory correct" (p. 46).

With regard to the first of these conclusions, it seems to me that the mere fact of the tablet being found face down at a height of 19 feet above sea-level is no proof that it always occupied that position. Mr Milne Home requires any one suggesting this "improbable view" to state some grounds for it, and (with all becoming deference and humility be it understood) I shall now state my reasons for disagreement with the whole of Mr Milne Home's inferences.

The tablet has niches in its back evidently intended for dovetailing it up into some building where it could be seen by an assemblage of persons. It is extremely unlikely that such a splendid piece of sculpture* would be laid on the ground like an old-fashioned tombstone exactly 19 feet above sea-level. Mr Milne Home's arguments under this head are also slightly contradictory, for at one place he argues that it must have been situated 19 feet above high water, since it was found there, and at another place he takes the more sensible view that it was set up on a wall from which it fell or was thrown down to the level at which it was discovered. Had it been set up in a wall 6 or 8 feet above where it was found, then it could quite easily have escaped the waves, according to Mr Milne Home's own reasoning; but we have no business at all to found any argument on such insecure premises, unless it be the argument that the tablet was never, in all probability, situated at a much *lower* level than that at which it was discovered.

In the second place, the neck of land being 23 feet high would only be covered with water to a depth of 2 or 3 feet for a short time during high tide each day, and it is evidently absurd to suppose that the Roman engineers were incapable of erecting a barrier of sufficient strength to resist the attacks of the waves for such a short period in every twelve hours. It is, moreover, not likely they would neglect to employ such a favourable site for the termination of their line of rampart, or be deterred from making use of it merely because the approach to it was covered by 2 feet of water when the tide was full. It is hard to see how a reasonably well built rampart could succumb to the waves in

* This tablet is I believe the largest and most elaborate piece of sculpture which has hitherto been found along this Roman wall. It is shown in the frontispiece in the Catalogue of the Antiquarian Museum, Edinburgh, where it now rests.

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such a situation, unless it be "waves of translation" to which Mr Milne Home refers.

In the third place, the old wall in question, which is situated a few yards north of the rocky platform where the stone was lying, is only *presumed* to be Roman. Mr Milne-Home unfortunately omits to state his reason for supposing it to be so. It consists of rough whinstone boulders, very unlike the neat squared sandstones the Roman masons were wont to use, a heap of which still bearing the old chisel marks was found a few yards from the spot. Although no local Edie Ochiltree can actually tell us that he "minds the biggin' o't" I suspect the antiquity of this "ruckle dyke" is scarcely so great as Mr Milne Home would have us believe.

The sea might thus have stood at least 20 feet above its present level at the time of the Romans for aught that Mr Milne Home's arguments, founded on his observations at Bridgeness, prove to the contrary. There are, however, two circumstances of which Mr Milne Home was unaware, which are almost conclusive that the sea *has not* retreated to any great extent since the beginning of our era. The first of these is, that the tablet was found among earth which was totally unstratified, so that the probabilities are strong that the waves have not reached the spot since the stone found its resting place. It was, moreover, *not* found resting on its face as it would have been had it fallen from a height, but it was found supported at the four corners and centres of the sides by small heaps of stones something like an old-fashioned tombstone. It was lying face down over a hollow in the ground deep enough for a man to creep through after the earth at the sides had been removed. The carving and inscription were perfectly clean and dry, and it is quite impossible the tide could ever have reached it, for the hollow below would either have been filled with stratified materials or marine organisms, of which there were no traces. I saw the stone a short time after it was discovered, and can endorse these statements, and it is my belief that ere the Romans were forced to relinquish Caledonia, they carefully laid this monument on its face in a hollow prepared for its reception, and covered it up so as to prevent the warlike natives from demolishing it. It was broken into three pieces, but this may have been caused by a heavy load rolling over it after being partially uncovered, at the time the Bridgeness Ironworks were being erected (1863).

2. *Beds above the Red Clay.*—The list of sections in the Appendix gives a general idea of the deposits which overlie the red clay. The surface silt or carse clay usually passes down into a more or less sandy bed which varies considerably in thickness, and is not nearly so rich in organic matters. Since

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the red clay occurs along the neighbouring shores up to a height of about 100 feet above mean sea-level, it is extremely probable that a large portion of it had been eroded "and a wide, broad trough scooped out of it, before the overlying carse clays could have been laid down; and it is unlikely that this erosion was the work of the sea" ("Prehistoric Europe," p. 401). The sands and gravels which fill this trough were brought down by the rivers which effected this erosion. The carse clay (or "silt" of the borers) as exposed in the Bo'ness dock excavations is, as already stated, a greenish blue or slate coloured rather tough mass, full of recent shells, sticks, and occasional boulders and trunks of trees, but I have never observed any peaty layers or evidences of an old land surface at any part of the bed. In sinking No. 6 pit at Bridgeness an angular whinstone boulder, measuring 3′ × 2′ × 1½′, was brought up from the bottom of the bed about 12 feet below the surface. Many base plates of *Balanus*, which Mr David Robertson who examined them thinks to be *B. porcatus*, were sticking to it, and a polyzoon, a species of *Membranacea*, was found adhering to one of them.

In the borings made at the east end of Bo'ness dock the red clay is almost immediately overlain by the carse clay, but towards the centre of the excavation the surface of the glacial bed slopes rapidly away, and an intervening bed of sand and gravel occupies the space between the two deposits, as the following journals indicate. The three bores Nos. 16, 3, and 1 lie in a straight line along the north side of the dock, extending in a west-north-west and east-south-east direction at a distance of about 160 yards above low-water mark. Beginning at the east end of the section we have

In No. 16:—

	ft.	ins.
Water, . .	8	0
Sandy silt, .	15	0
Hard sand, .	4	0
Stones, . .	0	6
Red clay bored into,	41	0
Depth, .	68	6

In No. 3, 500 feet from No. 16:—

	ft.	ins.
Water, . .	9	0
Silt and shells, .	10	0
Gravel and stones, .	1	6
Sandy clay,	10	6
Red clay bored into, . .	11	0
Depth,	42	0

In No. 1, at west side of Dock, 1250 feet from No. 16:—

	ft.	ins.
Water, . .	11	7
Dark silt, .	6	2
Stones, . .	1	0
Sandy clay, .	10	0
Sand, . . .	7	0
Sandy clay, .	6	0
Red clay bored into,	12	0
Depth, .	53	9

In the first of these sections the depth to the surface of the red clay is 27½ feet, in the second 31 feet, and in the third, which is 250 yards further west, 41 feet 9 inches, while in excavating for the foundation of the crane seat on the west pier 173 yards further on in the same line, the top of the red clay

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with its overlying boulder bed was found to be only 18 feet below high-water level. In another line of borings made parallel to that just quoted, but about 60 yards further north, the depths to the glacial bed were found in bores Nos. 15, 13, and 12 (situated at the same relative distances as the first set), to be 35, 37½, and 62 feet respectively, while the clay was struck in driving piles at the point of the west pier at a depth similar to that at the crane seat. There is thus, to all appearance, a trough eroded out of the surface of the red clay immediately below the old east pier, which is filled principally with sand and gravel. It may have been the course of the Avon in early post-glacial times, and if it be so I am glad to be able to state as a fact what Dr J. Geikie in the absence of necessary information was led to infer after an examination of similar deposits in the valley of the Tay and Earn ("Prehistoric Europe," p. 400–1). If this be the old course of the Avon, it must have hugged the (present) shore immediately to the west of Bo'ness, for in three borings (Nos. 9, 10, 11) made in the bay to the south-west of the harbour the top of the red clay was struck at depths of 23, 17, and 18 feet respectively. Nos. 9 and 10 are about 150 yards from the beach, as shown on map. The top of the clay was there full of stones which are probably an extension of the dock boulder bed. The probable course of this channel is marked on the map at *c.c.*

Recapitulation.—1. Upwards of 250,000 years ago, according to the calculations of astronomers and physicists, Scotland formed part of the European continent, and the land stood at least 300 feet higher in relation to the sea than it does at present. The river system differed little from that which now obtains, but the broad arm of the sea now called the Firth of Forth was then much narrower, existing only as a deep gorge cut out of the rock by a swiftly flowing and tortuous river. The basaltic ridge of Borrowstounness was then much higher, and probably stretched about a mile further north, where the greenstones thinned out and became replaced by a bank of sandstones whose tail sloped away towards the skerry known as Preston Island, round whose base the angry waters of the preglacial Forth seethed and gurgled as they hurried off towards the distant main.

2. As time rolled on, the climate, hitherto temperate, began to increase in severity. Glaciers, at first small but latterly of prodigious size, came creeping down the valley of the Forth from the distant Grampians, but not being able to accommodate themselves to the crook in the glen at Culross, and urged forward by an immense weight of ice behind, they moved on in a straight course with dogged perseverance, grinding down the softer portions of the Bo'ness ridge with all other obstacles to their path. Many times did these *mers de glace* melt back before the mild interglacial climes, only to return with increased size when

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the cold was renewed. During these interglacial periods brooks made their appearance, and grain by grain carried off nearly all the debris which the glaciers had left spread over the land, and sometimes they had even time to cut out minature glens in the underlying rock ere the returning deluge of ice all but effaced every trace of their existence.

3. The local glaciers at last grew so enormous that they all coalesced and swelled into a mighty ice-sheet whose thickness approached 3000 feet. It covered every part of the district, and flowed eastwards off the coast of Scotland, where, according to the most recent authorities, it split into two divisions which parted company opposite Fife Ness. The southern portion, after traversing the Lothians, wheeled to the right past St Abb's Head and thence into Yorkshire, while the northern, having picked up several characteristic fragments of the East Nuik, moved off with them into the North Sea, where it joined the vast Scandinavian ice-sheet, and with it swept round the north of Scotland into the Atlantic, leaving on the Orkneys, as it crossed them, several of the Fife blocks, which have acted as a kind of scent for future geologists to smell out the direction of its path.*

4. After the cold had reached its climax, the ice-sheet again broke up into local glaciers, which, after the recurrence of minor interglacial periods, dwindled down and finally shrunk back into the hills, leaving moraines, kames, drums, till, boulder clay, and erratics scattered in their wake.

5. The melting ice gave rise to immense rivers which rushed down the valleys, ploughing out much of the old till and still more of the newer boulder-clay, and bringing down large quantities of sand and gravel to be deposited over the eroded glacial beds. Britain was at this time continental, and the North Sea had no existence.

6. Precession of the equinoxes, acting in conjunction with high eccentricity on the earth's orbit, again brought on a glacial period. The sea rose to a height of about 100 feet above its present level, and its margin is marked by a terrace round the shores of the firth. The ice-foot fringed the coasts, and the water, freshened by large rivers fed by the distant glaciers, was often coated over with a thick covering of ice which rose and fell with the flowing and ebbing tide. The ice-formed mud brought down by the turbid rivers could thus be deposited as red clay in tranquillity below.

7. The returning milder climate was again accompanied by a retreat of the sea. Large rivers scoured down the surface of the

* See Messrs Peach & Horne's important paper on the Glaciation of the Orkneys, "Quart. Jour. Geol. Soc.," Nov. 1880.

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red clay and covered it with shoals of sand and gravel, as they had done to the old till long before. The land continued to rise, and the higher raised beaches with arctic shells mark the successive pauses in its elevation. The upheaval lasted till the floor of the North Sea was laid bare for the last time, and it ultimately became converted into a vast forest whose remains are to be seen at several parts of our coasts.

8. Submergence to the extent of about 50 feet again ensued, after which the sea retreated by successive jumps, the last of which took place upwards of eighteen centuries ago. The lower set of raised beaches were formed, whose fauna, flora, and general physical characters betoken the prevalence of the temperate climate we now enjoy ("Great Ice Age," p. 331).

IV. APPENDIX.

List of Sections of Drift Deposits in the Upper Part of the Estuary of the Forth.

A. Borings made along low-water mark eastward from the end of Bridgeness Pier.

No. 1 Bore, at Pierhead—

	ft.	ins.
Sand and mud,	33	0
Red clay (stoneless),	36	0
Blue clay and stones (till),	24	6
Surface of mud to rock,	93	6

No. 2, 130 yards east of No. 1—

	ft.	ins.	ft.	ins.
Silt and rubbish,	5	0		
Sand and shells,	1	6		
Soft sandy silt,	13	0		
			19	6
Sand and stones,	8	8		
Soft sandy silt,	3	4		
Sand,	8	9		
			20	9
Red clay (stoneless),			35	0
Sand, soft,			7	0
Rock not reached at			82	3

No. 6 Pit, nearly same as No. 3 Bore, 150 yards east of No. 1—

	ft.	ins.
Gravel and rubbish,	2	0
Bluish green mud, with sand and stones,	10	0
Sand, with mud and stones,	28	10
Red clay (stoneless),	33	0
Grey sand and stones,	5	6
Boulder-clay, red, about	0	8
Blue till, full of scratched stones,	5	0
Surface of mud to rock,	85	0

No. 4 Bore, 323 yards east of No. 1—

	ft.	ins.
Silt,	9	6
Carry forward,	9	6

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	ft.	ins.	ft.	ins.
Brought forward,			9	6
Sandy silt,	6	6		
Grey sand,	10	0		
Soft sandy clay,	6	0		
Sandy clay and stones,	2	0		
			24	6
Red clay,	30	6		
Dark sand,	0	6		
Red clay,	5	0		
			36	0
Sand and clay,	7	0		
Grey sand,	1	6		
			8	6
Dark grey clay and sand (till),			3	0
Surface of mud to rock,			81	6

No. 5 Bore, 600 yards east of No. 1—

	ft.	ins.
Mud, soft and sandy,	9	0
Carry forward,	9	0
Brought forward,	9	0
Mud, sand, and stones,	12	0
Red clay, clean,	22	10
Do. with sand ribs,	9	9
Do. with sand,	14	1
	46	8
Dark sand and stones (till),	2	2
Surface of mud to rock,	69	10

No. 6 Bore, 960 yards east of No. 1—

	ft.	ins.
Mud, soft,	7	4
Sand, clay, and stones,	1	9
Red clay, clean,	20	1
Do. with sand ribs,	7	3
Do. sandy,	5	9
	33	1
Sand, stones, and clay (till),	3	11
Surface to rock,	46	1

B. Borings at Blackness for proposed Bridge, 1865.

1. Up line (see Map), red sandy clay got on south side below silt; in centre, no bottom to silt at 142 feet; on north side, gravel bed below water at 54–67 feet from surface.

2. Middle line, red clay below silt on north and south sides; in centre, no bottom to silt at 133 feet.

3. Down line.

No. 1 Bore, 2 miles 8 chains from Pardovan—

	ft.	ins.
Water,	36	0
Silt,	75	0
Red sandy clay,	20	0
Depth,	131	0

No. 2, 2 miles 40 chains from Pardovan—

	ft.	ins.
Water,	54	0
Silt,	77	0
Red sandy clay,	18	0
Depth,	149	0

No. 3, 2 miles 70 chains from Pardovan—

	ft.	ins.
Water,	52	0
Silt,	53	0
Soft red sandy clay,	61	0
Depth,	166	0

No. 4, 3 miles 1 chain from Pardovan—

	ft.	ins.
Water,	18	0
Silt,	15	0
Brown sandy clay,	21	0
Blaes,	5	0
Depth,	59	0

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No. 5, 3 miles 20 chains from Pardovan—

	ft.	ins.
Water,	14	0
Dark silt,	2	0
Red sandy clay,	9	0
Red clay,	17	0
Fakey blaes,	2	0
Depth,	44	0

No. 6, 3 miles 70 chains from Pardovan—

	ft.	ins.
Water,	18	0
Silt,	39	0
Red clay,	12	0
Depth,	69	0

C. Borings between Inch Garvie and South Queensferry for proposed Bridge, 1870.

No. 1 Bore, 1650 ft. from south side—

	ft.	ins.
Water,	6	0
Silt,	10	0
Blue clay & boulders (till),	8	0
Blaes,	2	0
Sandstone,	0	6
Depth,	26	6

No. 2, 1700 feet from south side—

	ft.	ins.
Water,	8	0
Silt,	16	0
Depth to till,	24	0

No. 3, 2000 feet from south side—

	ft.	ins.
Water,	10	0
Silt,	25	0
Depth to till,	35	0

No. 4, at centre—

	ft.	ins.
Water,	37	0
Silt,	65	0
Depth to till,	102	0

No. 5, 200 ft. south of Inch Garvie—

	ft.	ins.
Water,	21	0

Stopped on whinstone.

No. 6, 48 feet north of Inch Garvie—

	ft.	ins.
Water,	33	0
Silt and clay,	7	6
Depth to whinstone,	40	6

D. Borings at Bo'ness Dock.

1. Line of Bores nearest shore, running W.N.W. and E.S.E.

No. 18, 180 yards north of Free Church—

	ft.	ins.
Water,	6	0
Sandy silt and rubbish,	14	9
Soft red clay,	18	0
Till, blue and sandy,	24	3
Blaes bored into,	2	0
Depth,	65	0

No. 17, 600 feet W.N.W. of No. 18—

	ft.	ins.
Water,	7	0
Sandy silt,	13	0
Stones (boulder bed),	0	6
Soft red and blue clay,	30	0
Blue till,	12	0
Depth,	62	6

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No. 4, 1100 feet from No. 18, in the S.E. corner of Dock (see Pl. III.)—

	ft.	ins.	ft.	ins.
Water,			7	0
Silt, dark,	9	6		
„ light,	4	0		
			13	6
Stones (boulder bed),			0	6
Dark sandy clay,			2	0
Red clay,			26	0
Sand and stones,			2	4
Till (blue sandy),			14	0
Depth to rock,			65	4

In this and the following section, the thickness of the red clay and underlying beds was found in borings made to the rock in April 1881.

No. 5, at south side of dock gate, 1850 feet from No. 18—

	ft.	ins.	ft.	ins.
Water,			5	7
Silt, dark,	10	9		
„ light,	8	0		
			18	9
Sand, gravel, and clay,			2	0
Red clay,			24	0
Sand and stones,			2	0
Till (dark sandy),			51	6
Depth to rock,			103	10

No. 7, at centre of West Pier, about 2680 feet W.N.W. of No. 18—

	ft.	ins.	ft.	ins.
Water,			10	11
Silt, dark,	8	0		
„ light,	6	0		
			14	0
Sand,			14	0
Red clay bored into,			20	0
Depth,			58	11

2. Line of bores parallel to first, including Nos. 16, 3, and 1, at same relative distances as, and opposite to Nos. 17, 4, and 5, but 280 feet farther north, already given at p. 26.

3. Line including Nos. 15, 13, and 12, also parallel and opposite to first, 460 feet farther north.

No. 15 (opposite No. 17)—

	ft.	ins.
Water,	12	0
Silt,	12	0
Sand,	11	0
Red clay bored into,	33	0
Depth,	68	0

No. 13—

	ft.	ins.
Water,	13	6
Silt,	11	0
Sand,	13	0
Red clay bored into,	34	0
Depth,	71	6

No. 12—

	ft.	ins.
Water,	15	3
Silt,	12	0
Sandy silt and boulder,	34	5
Red clay bored into,	13	0
Depth,	74	8

4. Line along outside of outer wall, parallel to third line, but 40 feet farther north.

No. 22, 200 feet N.W. of No. 13—

	ft.	ins.
Water,	15	5
Silt,	13	0
Soft sandy silt,	26	0
Soft red clay bored into,	11	0
Depth,	65	5

No 21, 220 feet W.N.W. of No. 22—

	ft.	ins.
Water,	15	4
Silt,	12	0
Soft sandy silt and stones,	36	9
Soft red clay bored into,	10	0
Depth,	74	1

Shown on Plate III.

No. 20, 440 feet W.N.W. of No. 22—

	ft.	ins.
Water,	15	11
Silt,	13	0
Soft sandy silt,	45	0
Red clay not reached at,	73	11

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No. 19, 800 feet from No. 22, and 320 feet due east of end of west pier, about the centre of supposed old river bed (C.C. on Map)—

	ft.	ins.
Water,	16	0
Silt,	10	0
Stones,	2	6
Soft sandy silt and gravel,	51	0
Red clay not reached at,	79	6

E. Miscellaneous Borings.

1. Borings for Charleston proposed dock, 1870, show red clay from 10 to 15 feet below high water level.

2. Borings across the Forth at Alloa Inch, show a bed of yellow clay and boulders at a depth of 6–17 feet below high water level.

3. Borings for Forth Bridge Railway, to south of Blackness, show the blue till to be overlaid by a bed of brown clay 1 or 2 fathoms thick, probably a surface decomposed layer of the till itself. This bed is yellow on some parts of Bonnytoun Hill.

4. Borings and sections to west of Linlithgow show the surface to be covered with beds of sand and gravel, sometimes 30 feet thick.

5. Bore at Low Manuel, west from Linlithgow Bridge (R. on Map, and section No. 3 "Trans. G. S. E.," vol. iii. p. 320).

	ft.	ins.
Moss,	4	0
Sand and gravel,	24	0
Sand and mud,	20	0
Sandstone beds (blocks) and gravel,	13	5
Sandy mud,	3	3
Sandstone and beds of mud,	3	0
Depth to rock,	67	8

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III.—*Notice of a Bore Section at Abbey Hill, and its relation to the Rocks of the Calton Hill.* By JOHN HENDERSON.

(Read 16th December 1880.)

The section I am about to describe has been exposed during the process of boring for water, by the Cumberland Diamond Drill Company, on the premises of Mr Robert Younger, brewer, Abbey Hill, and I am obliged to Mr James Melvin for the opportunity of examining these boring operations and the section brought up, as it was at his suggestion that the material was kept and laid out in regular order, and arrangements made for me to see it, at any time convenient. The principle of the tube drill is a very ingenious one, and a very interesting one to the geologist, as a nearly complete section of the rocks through which it passes can be brought up and laid out in a regular sequence for his examination, as has been done in the present instance.

The locality in which this bore is being put down lies about 250 yards east of the eastern entrance of the Calton Tunnel, in the Abbey Hill district of Edinburgh. The bore is already sunk to a depth of over 500 feet, and the following rocks have been perforated. The bore commences at the bottom of a well 33 feet deep, sunk partly through clay and drift and partly through shale. For the first 200 feet the bore passes through a series of light and dark grey and black shales, with nodules and one or two bands of impure limestones, and one of the hard dark-coloured beds of shale contained cavities filled with mineral oil. In one of the black shale beds I found fragments of two genera of fishes, viz., *Eurynotus* and *Rhadinichthys*, both of which are genera common to the Wardie and Granton series. This bed also contains a large number of *Entomostraca*. The next 100 feet the beds passed through are mostly brown shale with occasional beds of dark gray shale with nodules; at the depth of about 320 feet a bed of reddish porphyritic conglomerate, 10 feet thick, was passed through, then a brown felspathic shale followed by another porphyrite conglomerate, 5 feet thick, followed again by a bed of trap ash 13 feet thick. Below this there is a hard amygdaloidal greenstone, 12 feet 9 inches thick, carrying the bore down a depth of 360 feet. Below this again the beds pass through a series of porphyrys, porphyritic conglomerates, and amygdaloidal felstones, with occasional partings of ashy shales down to where the drill is presently at work, a thickness of 170 feet, making in all 530 feet.

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It will be seen from the nature of the beds passed through, and a study of the rocks in the neighbourhood, that they are now boring through a continuation of the beds of porphyry and tuff that form the rocks of the Calton Hill.

The rocks of the Calton Hill have been described by several eminent geologists. MacLaren, in his "Geology of Fife and the Lothians," quoting from Mr Webster, a pupil of Mr Jamieson's, mentions five alternating beds of trap tuff and porphyry as forming the hill; the highest bed, which is crowned by Nelson's Monument, is a porphyry, the second a trap tuff, the third porphyry, the fourth trap tuff, the fifth and lowest being a porphyry enclosing a mass of sandstone and shale, and in a foot-note he states that these sandstones and shales have been repeatedly bored for water to a depth of from 300 to 400 feet. Of the sedimentary beds that cover the trap tuffs and porphyrys, he gives a table of seventeen beds that were exposed in taking out the foundations for the buildings in Regent Terrace. Of the seventeen beds exposed eight consisted of bituminous shale, seven wacke, and two were thin beds of sandstone; the wacke he explains is a sort of earthy tuff so soft that it yields to the nail.

In the Memoir of the Geological Survey the Calton Hill is described as consisting of various felstones with ashy inter-stratifications resting on augitic rocks, and surmounted by shales and sandstones, and fifteen beds are enumerated as belonging to the trappean rocks of the hill, and is accounted for by supposing it to be a portion of the north end of Arthur's Seat, and brought into its present position by a fault, and they now stand exactly one mile apart. Professor Judd considers this a most important discovery made by the officers of the Geological Survey.

There is nothing in this section at Abbey Hill to prove or disprove this theory of the origin of the Calton Hill, neither does a careful study of the rocks in the neighbourhood confirm it.

The rocks that underlie the old and new town of Edinburgh present as great a geological puzzle as any in the county. In examining the various sections exposed, showing the dip, strike, and character of the rocks, and from the discriptions given by MacLaren and others, I find the beds arranged in something like the following order:—The beds on the south side, including the High Street and Canongate, consist of a series of thin bedded sandstones, and red, brown, and greenish shales, dipping to the north-east at angles of from 15° to 25°; the dip is uniform and steady from the Castle Hill to Arthur's Seat, a distance of more than a mile. These rocks are believed to belong to the lowest portion of the Carboniferous series, now referred to the Upper Old Red Sandstone by Professor Geikie. Such is the position and character of the rocks that underlie the old town; but when we

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cross the valley once known as the Nor' Loch (now Princes Street Gardens) to the new town, we find the position and character of the underlying rocks greatly changed. If we take a section parallel to the one from Arthur's Seat to the Castle, through the new town, say from the well now boring at Abbey Hill to the west end of Princes Street, we find the rocks in the eastern half of the section, including the igneous rocks of the Calton Hill, all dip to the east, while those of the western side dip to the west, forming an anticline in the centre about St Andrews Square. This was pointed out by MacLaren in his "Geology of Fife and the Lothians," and he first called attention to the unconformity of dip and strike between the rocks of the old and new town, and suggested a fault passing along the line of the "Nor' Loch," as the cause of this unconformity. Now the rocks that underlie the new town belong to the upper portion of the Lower Carboniferous or Calciferous Sandstone series, now termed the Cement Stone Group by Professor Geikie; but if the Calton Hill is a portion of the north end of Arthur's Seat, how then does it happen that the rocks underlying it to the west are so very different from the rocks underlying Arthur's Seat to the west. A fault would scarcely explain this. I offer these remarks to show the very unsatisfactory state of our knowledge of the rocks that underlie our own city, where hundreds of sections have been exposed during the building and draining operations which have been carried on from time to time, and to press upon the members of our Society the necessity of examining and noting every section which comes under their observation.

Now the bore section which I have described discloses one or two important facts in connection with the formation of the Calton Hill; for instance, it shows that the bedded tuffs and porphyrys dip under the stratified shales and sandstones to the east, and that the Calton Hill is only the outcrop of a more extensive deposit that lies buried under the sedimentary rocks, it also indicates that these beds were deposited in a nearly horizontal position, possibly under subaqueous conditions, and that they got gradually buried under the denuded and water-worn fragments of their own masses, as is shown by the great beds of rolled porphyry conglomerate through which the bore passes before it reaches the amygdaloidal greenstones and porphyrys of the hill. It also shows that the porphyritic and felspathic character of the sedimentary beds gradually disappears, indicating that these igneous beds were gradually getting buried out of the reach of erosion and denudation, and that ultimately the whole series was covered by a great thickness of black and grey carboniferous shales, of the Wardie and Granton series.

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With regard to the prospect of getting water, for which the bore is being executed, very little can be said. The bore is already down 200 feet into the trap rocks, with very little appearance of success, but it is quite possible that in passing through some of the stratified beds that lie between the porphyrys they may yet meet with a supply sufficient for the purpose required. The prospect of passing completely through the igneous rocks of the Calton Hill and reaching the sedimentary rocks below is not very encouraging, as I calculate that they will require to sink to a depth of 1000 feet at least before reaching the underlying beds.

We can only wish Mr Younger all success in this spirited enterprise, which will undoubtedly lead others to try the same system of boring, and give us more opportunities of examining these instructive sections.

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IV.—*On the Discovery of a nearly entire* Rhizodus *in the Wardie Shales.* By THOMAS STOCK, Natural History Department, Museum of Science and Art, Edinburgh.

(Read 16th December 1880.)

The fact of the occurrence of *Rhizodus* at Wardie has been known for a good many years. It appears as an addendum to a list of fossils from that locality published * in 1861 by the Geological Survey of Scotland. The specimens hitherto collected, however, have been the merest fragments, consisting principally of detached scales. Almost the first fossil obtained by the writer from Wardie was a badly preserved fragment of the jaw of *Rhizodus* containing teeth. Since then a few fragments have occurred referable to the same genus. From the fact that these were invariably found along a particular part of the beach, the suspicion was gradually awakened that they had been derived from a common source. This suspicion was confirmed by the discovery of the remarkable specimen which is the subject of this notice. It was found lying in the direction of the strike of the beds, its head seawards, its tail to the shore. The greater part of it was buried under from six inches to a foot of shale.

The end of the tail and the anterior portion of the head had been bared by the waves, and though the tail remains almost intact, the head has suffered a good deal from the erosion of the sea. The rest of the fish is preserved. As the bed in which it was entombed is accessible only at very low water, considerable difficulty was experienced in getting the specimen away; but, thanks to the help of Mr Macpherson of Trinity this was effected, and a noble fish has been saved to science.

It is undesirable at present to say much about the new facts which this specimen reveals. Much may be made out as to the shape of the fish and the position of the fins; but it would be unwise to give forth statements involving facts of great structural importance until these can be corroborated by examination of the fish, after it has been properly developed and displayed. It will be enough to say that it appears to be in a good state of preservation; that it is nine feet in length; and that it occurs in the form of an immense flat nodule. A few detached scales were found in nodules beside it; but beyond this and the injury the head has received from the sea, there has been no disintegration of importance.

* "The Geology of the Neighbourhood of Edinburgh," London, 1861.

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Appended are a few localities in the Calciferous Sandstone series of the district where *Rhizodus* remains have been discovered: Brickworks at Straiton; Oakbank, near Mid Calder; Burdiehouse; Arthur's Seat; Gowan's new quarry near Juniper Green, on the horizon of the Wardie shales. It was found by Mr Henderson at this locality in sandstone, an unusual circumstance.

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V.—*Recent Geological Changes on the Moray Firth.* By THOMAS D. WALLACE, F.R.S.A. Scot., Head Master, High School, Inverness.

(Read 6th January 1881.)

Introduction.—The purpose of this paper is to localise and describe certain physical features now to be seen in and around the Moray Firth. Before doing so it will be necessary to state clearly the exact area included in the following observations. That arm of the German Ocean usually known as the Moray Firth, is naturally divided into three distinct parts, as follows:—

1*st.* The most westerly portion, extending from Beauly to Kessock Ferry at the mouth of the Ness, is called the Beauly Firth or Beauly Loch.

2*d.* The second and middle portion is occupied by the Inverness Firth, and extends from Kessock Ferry to Fort George.

3*d.* The Moray Firth proper extends from Fort George to the German Ocean.

The whole is bounded on the north by the counties of Ross and Cromarty, and on the south by Inverness, Nairn, Elgin, Banff, and Aberdeen shires.

Area of Observations.—This paper is confined to the Beauly and Inverness Firths, and the south shore of the Moray Firth proper as far as Port Gordon. It takes up the geology of the shore where it was left in the "Geology of Rathven and Enzie," read before the Society (May 1880). It may be interesting to remember that the district under consideration includes the whole of the northern boundary of the "old province of Moray," which included forty-five parishes, and extended along the south shore of the Moray Firth from Beauly to a little beyond the mouth of the Spey.

Shores.—There is a remarkable contrast between the northern and southern shore of the firth. The former is with few exceptions high and rocky, and broken by Munlochy Bay and Cromarty Firth. The latter is with as few exceptions almost entirely low and flat, over which flow the rivers Beauly, Ness, Nairn, Findhorn, Lossie, and Spey.

History.—The history of this area is full of interest to the antiquarian and the archæologist. Although some doubt whether the Romans ever penetrated so far north, there is every probability that they did. If they circumnavigated the island; as they sailed into the mouth of the Moray Firth, the shores of Caithness, Sutherland, Cromarty, and Ross would appear to them

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as an island or the shores of another country, and they would naturally sail westwards, hoping to find open sea all the way. The Romans visited these parts not as settlers, but as explorers, and hence the scarcity of Roman remains. From history, tradition, and archæological finds, the old province of Moray must have been the scene of frequent incursions of the Danes and Northmen. But history is not our object here, and therefore we must forbear, and conclude with one interesting fact in its modern history, namely, that on the shores of this firth were born Hugh Miller and Sir Roderick Murchison, whose names will always be cherished with the highest veneration by every lover of scientific research.

Author's Motive in Publication.—Considering it to be the duty of every member of any scientific society to gather facts from which to form theories, and explain phenomena, and not to waste time gathering those facts which will support only those theories already formed without sufficient data, has alone induced me to lay before the Society the following facts, obtained by personal observation and from trustworthy information.

Beauly Loch.—This loch, which measures 10 miles long by 2¼ miles at its greatest breadth, is extremely pretty when viewed at high tide, and illuminated with all the glorious hues of a northern summer sunset, gilding Ben Wyvis and the Ross-shire hills in the back ground. Its shores, which are low, are well cultivated and sparsely wooded, afford here and there sites for several prehistoric as well as historic strongholds. Standing on eminences guarding the eastern entrance are the vitrified forts of Craigphadrick and the Ord of Kessock. The Gallow Hill, the grim monument of a former civilization, overlooks the baronial pile of Redcastle. On a well-defined portion of the 90 feet terrace which overlooks the western extremity of the loch, stands the house of Tarradale, the birthplace of Sir Roderick Murchison.

Name of Loch.—The River Beauly, like the Forth, Clyde, and others, may have originally formed and imparted its name to this great estuary. A branch of the river still retains the name Varrar, which it bore in the days of Ptolemy, and gives its name to one of the loveliest of our northern glens. The Vara Arstuarium and Sinus Vararis are names applied to this firth by those authors who have had occasion to mention it in the Latin tongue.

Physical Features of Loch.—The loch is very shallow, so shallow indeed that at low water a boat can with difficulty be navigated through its tortuous channels. The bed of the loch may be described as an extraordinary accumulation of sand banks with two well-defined channels between them, and which are kept open by the River Beauly, and the ebb and flow of the

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tides, which are very strong. The sand banks vary in form, according to their positions to the different currents.

It receives the waters of the Beauly River, Moniack Burn, Alt-na-Cardiach, Bunchrew Burn, and the waters of the Caledonian Canal. All these, flowing for considerable distances over the Old Red Sandstone area, supply the loch with the accumulations of sand referred to above.

Terraces.—In and around this loch there are many evidences of geological changes. On the north shore there are extensive and well-defined portions of the 90 feet terrace. At Kessock Ferry, which is the outlet of the lake, along with the fragments of the 90 feet terrace, are associated portions of other terraces of various heights and dimensions. All these rise seawards; that is to say, they are higher at their eastern extremities than their western. It is a little difficult to account satisfactorily for this seaward elevation.

Changes.—When the sand and mud, which are carried down by the streams into the loch, are met by the flowing tide, which, as has been said, runs very strongly in the narrow channels, they are thrown back and diffused over the sheltered bays and deposited through the quieter waters. This will ultimately raise the bottom of these bays, or in other words continue to make them shallower. While this must be the inevitable result of the present operations, it is also evident from facts now to be stated, that there has been a very extensive overflow or rise in the level of the sea upon some of these shallow bays. I have read and heard it frequently stated that the Beauly River, anciently called the Farar, once flowed as a river through the entire length of the "Moray Firth." "Although this might be in general presumed to have been the case, its application in any one particular may still be difficult. It requires no common exertion of the mind, even in idea, to represent this country before the excavation of the Moray Firth, when the highest lands of Birnie were continuously conjoined with the Sutherland hills, and no sea intervened between Duncan's Bay and Peterhead; but that the Varrar, receiving the waters which now constitute the Ness, Nairn, and Findhorn, in its course meeting with the Spey also on the south, and the Conon from the north boiling in rapid eddies around the Knock of Alves, rolled in one vast volume along the side of the hills of Enzie and Cullen, and discharged an immense cataract of extremely turbid water far eastward into the German Ocean."

Cairns.—From minute personal observation, evidences of this condition of things seem to exist in the Beauly Loch. From the mouth of the Ness and along the channels in the loch there is a series of cairns. Some of them bear special names, others do not, Cairn Airc (the Monument of the Sea) is at the mouth of

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the Ness, Cairn Dhu (Black Cairn) with another nameless one are on a sand bank. Further up the loch and near to Redcastle there is another large one with several smaller ones. These are considerably within high-water mark, and "from the urns that have been found in them" they must have been used as sepulchral mounds. As it is not at all probable that the primitive builders of these mounds would have buried their dead within high-water mark, the sea must have overflowed what was dry land when these people inhabited the shores of the firth. Again, as they would be originally placed at a considerable distance from the water's edge, our ideas are carried back to the period when the estuary terminated with the influx of the Ness at least, and the course of the Beauly alone winded along the margin of the vale.

This change may be accounted for in several ways, but we would suggest in passing that it may not be owing to any actual upheaval or depression of the land, but probably to the different alterations of the area of the firth.

At the depth of 30 feet below the Tarradall terrace, which is a portion of the 90 feet terrace, a deposit of hazel and alder twigs, leaves, and fruit have been found. This points to the growth and fructification of the trees previous to the deposition of these gravels. From the quantity of mussel and other shells, including the oyster, which are found in these gravels at Wester Lovat, and at the back of the schoolhouse at Beauly, it is evident they are of marine origin as far as their present arrangement and stratification are concerned. This shows conclusively that no change has taken place in the climate of the north of Scotland since the deposition of these gravels.

Changes in River Channel.—There are also most interesting and well-defined evidences of many changes in the channel of the Beauly River.

1*st.* Previous to cutting the gorge out of the Old Red Conglomerate at the celebrated Falls of Kilmorack, the river evidently flowed in a straight line from the top of the gorge towards Beauly.

2*d.* After leaving this channel it flowed past the Established Church Manse at Kilmorack, along the line of the present road to Beauly, which passes the manse.

3*d.* The most recent change which has taken place was when the river changed the course in one night, at a place below the "Falls of Kilmorack," which led to a lawsuit between the Bishop of Ross and the Bishop of Moray for possession of the land. The river when in flood still fills a portion of this channel.

4*th.* Another channel may be traced through Moniak Moss (now drained) in the parish of Kirkhill, into the firth to the east of Clunes Railway Station. The church and manse of Kirkhill

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stand upon the high ground which divides this old channel from the present course of the Beauly.

Inverness Firth.—The Inverness Firth extends from the mouth of the Ness to Fort George, a distance of 8½ miles. Its greatest breadth is 3⅛ miles. The shore on the north side is high and consists of Old Red Conglomerate, which comes down in many places to the water's edge. Munlochy Bay opens through this shore for a considerable distance inland. From Kessock to Fortrose fragments of terraces of various heights and dimensions are here and there to be met with, having a tendency to rise a little towards their eastern extremities. There are terraces on both sides of Munlochy Bay exhibiting the same features. These terraces form sites for the villages and mansion houses along the shore, as at Kilmuir, Avoch, and Fortrose.

Terraces.—The south shore is bounded by the 90 feet terrace, which rises to 117 feet as it nears the hills. Following this terrace from Inverness eastwards, it slopes gently down towards the low lying lands of Nairn and Moray shires. It can also be traced westward to Fort Augustus, Fort William, and Ballachulish. Its presence on the north shore of the Moray Firth has already been stated. It is cut through by the Ness and various streamlets which flow into the firth. Inverness is built partly on it, and a magnificent view of the surrounding country can be obtained from its highest parts. The terrace consists of gravel, sand, and boulder-clay, exhibiting all the different features of current bedding. Screetown Burn is cutting its way back from the sea towards the farm of Stoneyfield with marvellous rapidity, displaying on both sides very fine sections of boulder-clay. This cutting is 5 or 6 yards wide at the lower end, and narrows to a few feet at the upper, and is about 25 or 30 feet deep. The stones in the clay are all smoothed and rounded, but owing to their extreme hardness no decided striæ are to be detected on them. During heavy rains the stream carries down great quantities of this clay and sand to be deposited on the shore, in delta shape, through which its waters find their way to the firth by different channels.

Bays.—There are three bays on the south side, Culloden Bay, Petty Bay, and Campbelltown Bay, which are covered only at high water. Their low water marks may be roughly described as straight lines drawn from the eastern to the western points of the bays.

Petty Bay is shallow and muddy, and on its south shore lies a large boulder which was, on the night of the 20th February 1799, removed seawards about 260 feet. The stone marked the boundary between the lands of Culloden and the Earl of Moray, and many are the explanations given of its removal. Some say it was done by an earthquake; but the general opinion seems to

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be that a large sheet of ice, having frozen fast to the stone, was the means, with the help of wind and tide, of changing its position. In this bay there was once a tide mill, remains of which are still to be seen.

Oyster Deposits.—Formerly oysters must have been plentiful in all these bays, as can be proved by the numerous deposits of shells under the sand and mud. At the mouth of the Millburn near Inverness, and in fact all along the shore, there are great deposits of oysters and other shells. In 1758 there were oysters in Petty Bay. But forty years after that they are reported to have disappeared. They are still in the firth, and smacks from England come to dredge for and carry them away to southern markets.

Clay Deposits.—There are several deposits of very fine clay in and around the south shore, which seem to have been deposited in hollows or pools through quiet waters. The deposit at Culloden Tile Works is interbedded with fine sand, and is about 11 feet thick. It shows fine bedding, but is almost destitute of stones; as yet no shells have been found in it. The strata exhibit undulations, which could not have been the result of pressure, but simply of the clay deposited on an undulating surface, probably indicating the contour of the smoothed rock underneath. The different beds which dip and thin off towards the north might be accounted for by different periods of deposition, between which the beds of sand would be laid down by currents. A deposit of blue clay is to be seen at different points on the shore, and one near Fort George may be here mentioned which contains shells in great abundance.

Changes at Campbelltown.—Between Campbelltown and the fort the sea is gaining on the land, or rather on the deposits of gravel which the sea has at some former period laid down here. On the north side of the fort the sea is gaining very rapidly on the land. These are to be accounted for by the action of the currents from the west and north-west, which are the combined results of the wind and ebb tide. The material carried away from the Campbelltown side of the fort is deposited on the point to the west of the fort, while that taken from the north side of the promontory is carried eastwards to assist in the accumulation of land on Whiteness Head. Between the fort and the carse wood there are three ridges of gravel (similar to those at Lossiemouth), extending for about 3 miles long and 12 yards apart. Between Fort George and Nairn there is perhaps the most remarkable reclamation of land to be seen on the whole shore. The present tenant of the farm of Ellismore—Mr M'Pherson—says that seventy-six years ago, when his father was a boy on the same farm, the tide in one hour rose over the land as far as 1000 yards from the present high-water mark.

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During this high tide his grandmother took to bed with six lambs to save herself and her pets from a watery grave.

Whiteness Head.—About fifty years ago high-water mark was 300 yards farther inland than the present, and within the last twenty-five years there has been a gain of over 100 acres of land along the shore. The whole of Whiteness Head consists of a series of sand banks which are dry at low water, and the outer one is seldom covered even at high water. To all appearance the whole of Whiteness Head will very shortly become the property of the farmer, by the natural accumulation of sand heaped up by the north-west and north-east tides.

There is another agent in the same locality working hard to bring about the same result, namely, a tongue of land extending from opposite the fisher town of Delnies, westwards towards Fort George for a distance of about 1½ miles. This accumulation has been formed within the last sixty years, and consists largely, if not entirely, of gravel, pebbles, and shingle scooped out by the north-east current striking on the shore to the west of Nairn. The action of the sea is so much felt at this latter point that it is sought to be counteracted by artificial walls. Once this tongue of land extends as it is rapidly doing to Whiteness Head, the sea will be shut out from hundreds of acres that can be speedily turned to agricultural purposes.

Nairn.—On the south side of the town of Nairn, on the bank of the river, is the Castle Hill where stood the royal fort of which the Thanes of Cawdor were hereditary constables till the year 1747. The constabulary garden is still distinguished as an article of the valuation of the estate to the extent of £3, 10s. Scots. At a very remote period of antiquity the castle was situated near to the shore, upon the influx of the river, which, similar to the Spey and Findhorn, then flowed half a mile farther westward than its present termination. There were some persons alive in 1798 who remembered to have seen at spring tides vestiges of its foundation, at present a considerable way within the bed of the ocean.

Culbin Sands.—The sand hills of Culbin stretch from the mouth of the Findhorn to Nairn, a distance of 9 miles. This used to be one of the most fertile parts of the proverbial "Granary of Moray." When other parts of the surrounding country were uncertain in their yield of crops, the Baron of Culbin had nothing to fear. Notwithstanding its former fertility, there is now nothing to be seen but a wide waste of constantly shifting sand. After strong west winds some of the soil is frequently laid bare, and the furrows left by the plough previous to its devastation, are distinctly to be seen; and what is in some respects more interesting, the tracks of cart wheels as they had crossed to and from the shore. Valuable

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relics of prehistoric days are picked up in several places from which the sand has been blown. These seem to be chiefly on the old banks of the Findhorn or on the old sea beach. Remains of shell mounds or "kitchen middens" are to be seen, with split bones, deer horns, flint arrow-heads, coins, bronze keys, fragments of pottery, hooks, nails, copper fastenings, and beads made of vitrified glass. Remains of the same ridges of gravel, so often mentioned in this paper, are also at times laid bare by the wind.

Before this accumulation of sand the annual rental of the Barony of Culbin has been computed to be £6000. In the year 1694 or 1695 the estate was almost entirely overwhelmed, or at least to such an extent as to cause in July 1695, Alexander Kinnaird, the proprietor, to petition to be exempted from paying the public dues, because, as he said, the best part of his estate was destroyed "so that there was not a vestige to be seen of his manor place of Culbin, yards, orchards, and mains thereof, and which within these twenty years were as considerable as many of the county of Moray."

Theory of Sand Hills.—Whence all this sand? is one of the most interesting questions in connection with this and other similar accumulations on the south shore of the Moray Firth.

While sand is no doubt carried down to the sea by the rivers which enter the firth, yet one greater source seems to me to be the washings of the shore, combined with the westerly flow of the tides. This is especially the case between Nairn and Fort George, where hundreds of acres of pure sand have been and are still accumulating. Then in Burghead Bay the same washing is going on and the sand carried westwards by the tide. This sand is thrown up on the shores, dried in the sun, and its fine particles raised by the wind and carried inland.

Findhorn.—The present village of Findhorn is said to be the third that has been built. The first was 6 miles to the westward of the present one, and is now covered up completely by the Culbin Sands. The second was to the north-west of the present village, and had to succumb to the same enemies that had overwhelmed its predecessor. What is now the north end of the village was the south end, in the recollection of the very oldest inhabitants. "A slip or ridge of ground along the shore on the western side of the River Erne appertains to the parish of Kinloss (1798) and to the estate of Muirtown. About a hundred years ago (1698) the river flowed westward nearly 6 miles converging with the shore. When the river gained its present direct course, this ground, by the water stagnate in its former bed, became an island, for many years affording secure pasturage for sheep and cattle; but by the drifting of the sand this ancient channel is now filled up, so as to be an island only

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during high water, divested of much of its accommodation, and the pasture greatly injured by the overspreading sand."

"Prior to the year 1701 the town of Findhorn, regularly built, stood upon a pleasant plain, a mile north-west from its present situation, and now the bottom of the sea. The eruption, though completed in one night and by one tide, had long been apprehended, and the inhabitants had gradually withdrawn. It is probable that the drifting sand accumulated by the united power of wind and tide, dammed back the river, forcing open its present course, and overwhelming the village."

Burghead Bay.—At that time a pretty level moor stretched in a right line along the shore from Findhorn to Burghead, for the distance only of 5 miles. The encroachment of the sea in a semi-circular bay has made the distance now by land a little more than 10 miles. The inhabitants of Findhorn were in a great measure supplied with fuel from this moor, the cutting up of which might have been the cause of the encroachment. On this moor near the shore stood a conical mound evidently artificial, about 40 fathoms high. It was called the Douff hillock, and afforded a view of the firth and the whole country round. An old man living in 1798 had gathered berries among the heath round its base. Many roots and trunks of trees were then found in the moor, and a few are still dug in the Moss of Hatton, confirming the truth of the tradition that a forest once occupied what is now the bottom of the sea and the downs between Findhorn and Duffus.

Changes.—The sand banks afford a feeble barrier to the power of every storm from the north, by which they are themselves forced further on the shore, and banks of peat earth are thereby discovered 6 or 8 feet below the sand. Within the flood-mark of the bay of Findhorn, where the estate of Muirtown borders with West Grange, in the year 1787, pretty extensive beds of peat earth were discovered, deemed such a treasure at first as to excite a lawsuit, as on the records of the Sheriff Court, between the landlord and his tenants, even for the duration of the current leases; but after the commencement of the litigation it was found that this fuel had such an offensive smell, and such corrosive power on kitchen utensils of copper and iron, as to be absolutely improper for any domestic purpose. This peat was found at a depth of 2 or 3 feet under the sand, not in a continuous bed, but in detached banks, as if covered by sand when formerly used, in a period beyond the remembrance of the passing generation.

At the present day, while the bay between Findhorn and Burghead is gradually sinking, so that the traces of the old forest have almost entirely disappeared, the land at Findhorn is accumulating. This is accounted for by the action of the tides and currents in the bay. The chief current is from the north-

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east, which strikes upon the shore between the Mill Burn and the Bessie Burn; but is strongest in the neighbourhood of the latter, and carries the gravel and sand along the shore westwards to Findhorn.

Findhorn River.—The same action is filling up and altering the mouth of the Findhorn. So much so is this the case that not many years ago there was a sand bank in the mouth of the river which formed a passage between it and the shore, called the "Ee" (Eye), through which ships used to pass. This "Ee" is entirely filled up now, and what was formerly an island of sand is now connected with the Findhorn shore.

The present village of Findhorn is, in the mean time, in no danger of sharing the fate of its two predecessors.

Between Findhorn and Forres there is a large bay about 3½ miles long and 4 miles broad, entirely covered by the tide at high water, but left dry after the ebb, with the River Findhorn flowing through it. It receives the Findhorn River, Forres Burn, and the Kinloss Burn, all of which carry down (especially the Findhorn) mud and sand in great quantities.

There are only two boulders in this bay, one of granite and the other of gneiss, which must have come from the south-west.

Burghead.—Burghead stands upon a bold headland of Upper Old Red Sandstone, surrounded almost by the sea, and considered by some to have been an island. To the south of Burghead there is a great accumulation of sand hills, composed of blown sand, which extend westward as far as Nairn.

Much has been written with regard to the origin of Burghead. Some maintain that it is of Norse origin, and others bring forward proofs to establish its Roman origin. Its geological history is equally interesting. The headland consists of a portion of the famous reptiliferous sandstones of Elgin, covered by an artificial deposit of earth and stones. The sandstone exhibits fine examples of the usual current bedding; one section shows the direction of the chief currents to have been from the south, with others from the north, and masses of pure quartz pebbles terminate the wave or current. The hard rock is interbedded with soft ferruginous sand. There are numerous examples of sun-cracks in the cliff overhanging the sea on the "head." The cliff indicates clearly the sea-level at a former geological period, for at the height of 30 feet above the present high-water mark there is a bed of gravel 3 feet thick, containing a deposit of marine shells covered by 3 feet of black peaty soil, which is capped by an artificial layer of 4 or 5 feet thick. The latter was probably at one time much thicker.

On the authority of people still living, the sea is rapidly encroaching on the land, to the west of the "head," but slowly receding on the east. About one hundred and fifty years ago

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the children of Burghead used to be able to pass from there to Findhorn on the stumps of the trees of the submerged forest. Burghead Bay measures in a straight line to Findhorn little more than 5 miles, and 1¾ miles from this line to the shore at the widest part. The shore for 1¾ miles, to the Mill Burn, consists of sand hills, and from thence to Findhorn of accumulations of gravel ridges, about 8 or 10 feet above the present high-water mark. The bay itself consists of sand, covering an extensive peat moss, with the remains of the old forest resting on a deposit of blue clay.

Changes on "Head."—It is evident from the deposit of shells on the "head" that high-water mark was at some former time 30 feet higher, or that the land was 30 feet lower than at present. The land then rose, leaving the greater portion of the old province of Moray a marsh, with the Hill of Alves, Rosisle Hill, and other high lands as islands. Gradually moss grew and trees sprang up into a forest. Then another submergence took place, and this moss and forest were covered with a deposit of gravel to the depth of 8 or 10 feet. Then the land began gradually to rise *into its present position,* and the action of the waves and currents to eat into, and carry away the gravel, and lay bare the forest.

Gravel Ridges.—On the authority of people now living, great changes have been, and are still taking place. The sea is rapidly encroaching upon the land. The old road to Forres used to be within the present high-water mark. Again, the sea is cutting into the gravel banks, and washing and rearranging the gravel in ridges on the shore, in a similar manner to those ridges already referred to. The tides from the north-east are gradually conveying this gravel and sand towards Findhorn, and working the changes before mentioned. These old gravel ridges, which extend from Hatton to Findhorn, are about a mile in breadth, and are as bare and entire as the day they were left by the tide.

They are of various heights, and measure from crest to crest 3, 4, 6, 8, 12, 14, and 20 yards.

About 2½ miles to the south of Burghead there is a farm called "Buthill," which some say is a corruption of "Boathill," and is pointed out as the place where the ferry landed or embarked passengers from Rosisle and Burghead. This is open to question; but the following can be relied on:—"Near the eastern end of the Duffus Valley there is a place called 'Ardivot' (the Hill of the Boat). A gentleman still in the neighbourhood has seen persons who crossed by this boat."

Lossiemouth.—The village of Lossiemouth, as its name implies, stands at the mouth of the Lossie, on a flat sandy plain very little above sea-level. Near the mouth of the river, and situated

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on an elevated rocky peninsula called Coulard Hill, stands the thriving village of Branderburgh. A little to the west the beautiful little village of Stotfield is situated on a grassy slope, facing the firth.

The changes that have taken place in this locality in recent times are something wonderful. The old harbour of Lossiemouth, which was opposite the site of the present railway station, is now in ruins, having fallen a helpless prey to the violence of the north-east currents which constantly beat against it. The old harbour of Stotfield is also in utter ruins, and has almost entirely disappeared under the sand. While making the harbour at Branderburgh, all the rubbish was thrown into the sea. This has been carried westwards by the tide and deposited in a ridge along the shore above high-water mark, as far as the mine at Stotfield. This ridge is from 10 to 12 yards wide at the base, and from 5 to 6 feet high at the crest.

Coulard Hill.—The Coulard Hill is composed of the Upper Old Red Sandstone, which has proved highly fossiliferous. Upon this sandstone there is a deposit of flinty rock, which is known as the Cornstone of Elgin, and which may be seen on the shore from Branderburgh to Stotfield, and has proved at the latter place to be highly charged with galena and several of the allied minerals.

Lossiemouth Lead Mine.—The following is a short account of the mine and some of the minerals, supplied by one of the gentlemen in connection with it.

"*White Sandstone or Freestone with Galena intimately associated.*—I have traversed this deposit and discovered what appears to be a true fissure vein, having a mean bearing to the south-west and north-east, entering the strata at about an angle of 80°, with a well-defined footwall to the north-west, and, as usual in such cases, very wide on the top, carrying good ore for nearly half a mile in length. As to its continuing so large and rich down to any great depth remains to be proved by exploration. I have found the ore in this rock at a depth of 45 feet from the surface.

"*Red Sandstone.*—Of this rock the Skerries opposite the mine are composed. There are several ridges, the lines of which can be distinctly seen at low tide. They are parallel, lying east and west, and those points which are always seen are the highest points of some of the ridges. Opposite the shaft there is an outcrop of silicious spar, highly charged with galena, in fact I broke therefrom a rock of ore, over a ton, four-fifths of which was galena. Here also I may mention, two lodes form a junction. At such points we invariably find master-lodes very rich, and all lodes, however insignificant, take a decided favourable change where such occurs. This is a point of great importance

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to the precious metal miner. Here also, at this particular point, we can more clearly notice the junction of the lodes imbedded between the white and red sandstones. This fact I consider the leading cause of the deposit being so large, 169 feet wide. We have therefore the lodes forming a junction as well as the white and red sandstones merging into each other. Each rock appears, and particularly the red, to be metamorphosed at first sight, while on closer examination it will be seen that their close firm texture is owing to their being highly charged with silicious matter.

"*Galena and Silicious Spar.*—This mineral is most abundant here. It occurs in smallest quantities in the very hard and almost pure silicious rock. I have frequently observed in other localities where we have the true crystalline rock, the lodes are always richest. The ore in this locality contains 75 per cent. of metal, together with 3 or 4 ounces of silver to the ton of mineral.

"*Phosphate of Lead.*—This is a very rare variety of lead ore. It usually occurs crystallised, solitary, or in groups, forming hexagonal prisms with basal planes, often modified by faces of the hexagonal pyramid. It usually contains about 70 or 80 per cent. of metal.

"*Galena and Blende, or Zinc-Ore.*—This is a very common and faithful associate of lead-ore, occurring crystallised and amorphous, forming the rhombic dodecahedron, octohedron, &c., often hemihedrally modified, and frequently twined, the forms being often difficult to determine.

"*Mundic or iron pyrites*, with silicious spar. Very common.

"*Carbonate of Lime.*—Crystallised or calcareous spar. Lustre often more or less shining, between vitrious and pearly colour; very various, usually more or less transparent and double refractive, often associated with galena.

"*Galena with copper* frequently found associated, especially in deep mines.

"*Gossan.*—This mineral is principally composed of spar and iron, frequently found on the top of rich metallic lodes, and where any quantity exists, there is usually a good deposit of mineral. The gossan itself usually carries silver ore in the form of very fine sand, in which case it is sent off to the smelter just as it comes out of the vein. Gossan seldom holds down deeper than 20 fathoms or so, when some other lode takes its place, with a rich course of ore continuing."

Buckie to Covesea.—There can be no doubt that the waters of the Moray Firth from Buckie to Covesea, which is a distance of over 20 miles, are receding from the land. This is not caused by the mass of land rising, but by the sea banking itself out with the aid of the wind. Some of the present old inhabitants of Stotfield say, that within their memory, spring tides used to

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flow in on a level piece of ground immediately under the village. This is now green sward upon a very slight covering of vegetable soil overlying shingle. Within the last six years several acres of shingle have been formed on the beach, which has been gradually filled up with sand blown from the shore during ebb-tides. The formation of the beach between Branderburgh and Stotfield would naturally have caused the sea to overflow the flat land to the east of Stotfield, but this has been prevented by the sand accumulating in this bay and thus banking out the water.

Lossiemouth to Kingston.—From Lossiemouth to Kingston at the mouth of the Spey great changes may be seen taking place daily. Travelling from Lossiemouth to Kingston, 6 miles of pure sand are first got over, which, when dry, is very liable to be drifted by the wind. It is generally carried southwards and formed into enormous banks, which if not covered with bent would be constantly shifting. These 6 miles are succeeded by 3 or 4 miles of pure shingle, which at their widest part are from three quarters of a mile to a mile. This shingle is continued in one great bank as far as Portgordon. The village of Kingston is built not only on it but of it. Their gardens consist of earth that was from time to time brought as ballast in the numerous ships which used to visit its busy harbour.

River Spey.—The changes at the mouth of the Spey are very remarkable, although they have proved most disastrous to the inhabitants of this interesting little village.

The Spey in flood is a very dangerous neighbour. This was painfully true in 1829, when so much damage was done to life and property. The amount of debris carried down in that year must have been enormous. As a proof of its carrying powers, when the bridge of Fochabers was carried away by the flood of 1829, some of the largest stones were found at the sea in the mouth of the river. Twenty-six years ago the mouth of the river was fully half a mile to the west of its present mouth. The place is marked by a solitary house on the beach. At the same time a new mouth was cut for it about 200 yards from its present mouth eastwards, which is now also filled up with gravel. So rapidly is the river again seeking westwards, that in the months of June, July, and August of this year (1880) it had gone fully 20 yards to the west, so that the tendency of this as of all the other rivers on the south shore is to go westwards. In the opinion of several persons who have given attention to this subject, the Spey once flowed through the valley now occupied by the Great North of Scotland Railway between Elgin and Rothes. The Spey is no doubt the cause of the accumulation of gravel on the shore between its mouth and Lossiemouth. The gravel carried down by the river is cast upon the shore by the

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action of the strong westerly tidal wave. There is now a delta at the mouth of this river, which is gradually filling it up as well as the harbour, where twenty or thirty years ago many ships could lie at anchor. The land along the right bank of the Spey from Fochabers seawards is very flat, and bounded by an irregular line of high terrace which runs from Fochabers to Portgordon. On the left bank the land is high, corresponding to the terrace on the right. At Garmouth it deflects to the west, and may be said to end with the Black Hill, an enormous accumulation of sand and gravel.

Loch Spynie.—Mention might here be made of the Loch of Spynie and the Lossie. History tells us that the loch continued an arm of the sea down to 1397. "It is proved from the chartulary of Moray," says Mr Young in his "Parish of Spynie," "that Spynie was a town and harbour inhabited by fishermen, who sailed from Spynie to the sea, and that boats and nets were kept by the bishop, Alexander Bar, in the lake for catching salmon, grilses, and other fish, and that he and his predecessors had exercised all acts of navigation therein." This loch, which was more than 3 miles long and 1 broad, is now drained, and the sea is at a considerabe distance from it. Perhaps the most extraordinary ridges of gravel on the whole shore of the firth are to be seen between this loch and Lossiemouth; but they must be seen to be thoroughly understood.

Conclusion.—In conclusion, attention is directed to the following facts :—

First. All the rivers that have been mentioned in this paper at no distant date entered the firth at points considerably to the west of their present outlets, and they are again tending in that direction.

Second. Some of these rivers have not only changed their mouths but their channels for considerable distances.

Third. All around the shore of the firth there are beaches or terraces of different origins and of different dimensions.

Fourth. In some places the sea is gaining upon the land, and in others the very reverse is taking place.

Fifth. These accumulations are almost entirely confined to the south shore.

These and many other interesting facts demand attention, and raise questions which we cannot here wait to answer.

The author hopes at some future time to be able to return to this subject, when he will supply any additional facts that may have been overlooked, and give what seems to him to be the explanation of some of the more interesting features.

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VI.—*The Recent Formations and Glacial Phenomena of Strathnairn.* By JAMES FRASER, C.E., Inverness.

(Read 6th January, 1881.)

Subject of Paper.

The paper read by Mr Wallace before this Society, in February 1879, gave an account of the rock formations of the Strathnairn district. The intention of this paper (which may be considered as a supplement to Mr Wallace's) is to give some account of the boulder-clay, gravels, and other recent formations found overlying the Gneiss and Old Red Sandstone, and of the extraordinary evidences of glacial denudation exhibited by the rocks and boulders.

Description of District.

The River Nairn flows in a due north-easterly direction. Its drainage area is 30 miles long and from 2 to 7½ miles wide, the narrowest point being at the parish church of Daviot, about midway between the source of the river and the sea. It will be well to note, at the outset, the position of the church of Daviot on the map, as it forms a convenient point for reference. On the east side of the river, and opposite the Daviot church, is the Craggie Burn, and 4 miles south-east of Craggie is Loch Moy, both of which will be afterwards mentioned. The watershed between the Nairn and the Findhorn runs in a crooked line along a range of high, smooth-topped, and heath-covered mountains of gneiss and granite rocks, from Carn-nan-tri-Tighearnan, 2013 feet high, at the source of the Cawdor Burn, to Carn Ghriogair, 2637 feet high, at the extreme source of the Nairn. The three lowest points or gaps in this watershed are,—(1) the opening above Craggie, through which passes the parliamentary road from Inverness to Perth, about 920 feet above sea-level; (2) the pass, 2 or 3 miles farther west, through which General Wade's Road was carried, at a height of about 1000 feet, and where the "rout of Moy" took place in the '45; and (3) a pass, 6 miles west of Daviot, at a height of 1450 feet, through which a rough district road leads from Farr in Strathnairn to Kyllachie on the Findhorn. Such is the eastern watershed of the valley. The watershed on the west side is of quite a different character, and composed in a great measure of the Old Red Sandstone. From Kildrummie near Nairn to Loch Duntelchaig, the line of watershed follows the low flat ridge known as Drumashie, which is coated to a greater or less degree with a clayey or gravelly till, partly under

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cultivation, partly planted, and partly under its natural heather. To the east of Daviot the general level of this ridge varies from 320 to 720 feet above sea-level, or from 120 to 270 feet above the bed of the river; and to the west of Daviot it varies from 760 to 900 feet above sea-level, the lowest point, about 2 miles west of the Dune of Daviot, being only 220 feet above the level of the river. It is interesting to note this, because, as will afterwards appear, the ridge, low as it is, was sufficient to conduct the last glacier along the windings of the valley now followed by the river. And this is all more remarkable, because there are three other openings or gaps in the extreme south end of the western watershed which are but very slightly elevated above the bed of the river:—namely, (1) the opening between Aberarder and the River Farigaig at Dunmaglass; (2) the valley occupied by Loch Ruthven, which flows into the Farigaig, but appears to have at one time discharged into the Nairn; and (3) the valley of Loch Duntelchaig, a tributary of the Nairn, opening over the low ridge between it and Loch Ashie, towards the valley of the Ness. The question may be asked, why did not the last glacier of the Nairn valley break out at these openings? The answer is that Stratherrick and the Great Glen were, at the same time, occupied by a glacier which met the Strathnairn glacier in these gaps. So much for the general configuration of the ground.

Wide Gap in the Geological Succession.

In all likelihood the district was at some time covered, more or less, by a greater extension of the Old Red Sandstone, and by some of the rocks of a more recent date. But if so, the later rocks have been utterly swept away; and the boulder-clay, ground off the Silurian and Old Red Sandstone rocks, is now found lying upon the Old Red Sandstone and gneiss. What changes may have come over this valley, and what successive denudations it may have experienced during the countless ages represented by the successive rock systems not found in it now, it is impossible to say. But it is evident from the configuration of the gneiss rocks and other indications that it existed as a river valley since the time of the Old Red Sandstone, which forms the greater part of its western watershed. The Old Red Sandstone itself seems to have commenced with a great glacial period of an infinitely older date than that in which we are specially interested on this occasion. This seems to me to be very strongly indicated by the peculiar way in which the underlying rock is splintered and bent at the junction of the gneiss and the Old Red Conglomerate on the Dunchea Hill, near Loch Duntelchaig, so fully described in Mr Wallace's paper referred to.

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Indications of a Glacial Period.

But, coming to the recent or Post-Tertiary period, to which the boulder clay and its concomitants belong, we find that unmistakable traces of the last glacial period are remarkably plentiful in Strathnairn. The hill tops are rounded, smaller rocks in the hill sides and on the flat ground are polished and rounded on one side, while the opposite side is rough and abrupt; parallel grooves and scratches, indicating the direction in which the ice travelled, are still visible on many rocks, and can be easily distinguished from the lines of fracture or strike natural to the rocks; extensive patches of the older till, or boulder-clay, ground off the native rocks, are found at all levels up to a height of 1700 or 1800 feet above sea-level; and there are great banks of the later gravelly tills, and fine sand which I believe must be ascribed, almost entirely, to the operations of glaciers or land ice; and lastly, there are multitudes of travelled boulders far away from their parent rocks, and of all shapes and sizes,—sometimes lying on the naked rocks or moorland, and sometimes embedded in or lying on the upper gravels and sand.

The Glacial Period.

It will perhaps be permitted to me here to describe, so far as that may be done in a few sentences, what I conceive to be the orthodox view, and the view on which my ideas are founded, regarding the nature of the glacial time, and the mode in which the glaciers operate on the rocks and looser materials. After the close of the Tertiary period, or 200,000 years ago, as some of our geologists have attempted to fix the time, the whole of Scotland, in common with northern Europe and northern America, was for long ages covered with a perennial covering of snow, which is supposed to have been from 2000 to 3000 feet in depth reckoning from the sea-level. Such is the condition of Greenland to this day. Instead of accumulating on the hill tops to an indefinite extent, a great covering of snow like this is found to move constantly towards the sea, just as water in the liquid form will do, but by an infinitely slower motion, and in a manner peculiar to itself.

Glacier Motion.

The pressure of its own weight, and the alternate thawings and freezings of the surface of deep masses of snow, will gradually change it into ice. This land ice, as it is called, is found to have the peculiar property of creeping or flowing slowly at the rate of from 1 to 3 feet a day, from the mountains downwards to the sea, until it terminates from gradual decay in the low grounds, or is broken up and lost, far out in the ocean.

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And it is no matter how rough and irregular the ground is; for, in the case of a great ice-sheet that is level across hills and valleys, it will creep straight on over the lesser hills and rocks; and in the case of an ice-river or glacier, that only partially fills a valley, it will fill up the hollows and conform in shape to the irregularities of the ground, and will flow right over all rocks and obstructions that are not too high to be covered by the ice. The ice cracks and splinters in all directions as it goes, but when under great pressure it has in itself the property of gradually reconnecting all cracks and crevasses caused by the irregularities of the ground. It is important to note the full meaning of the fact that land ice when in a great mass will "flow" straight on over all lesser obstructions. In the case of a flood of water flowing down a valley and meeting with a lake basin, it first fills the basin and then overflows towards the sea, the water in the bottom of the lake remaining quite motionless, or only gradually mingling with the water at the surface, according to circumstances of temperature, &c. In the case of a glacier taking the same course, it will fill the lake basin nearly in the same way, until it becomes a lake of solid ice and begins to overflow. But after that stage is reached it is not an overflowing that passes onward. It is the whole mass of ice that moves forwards, creeping with irresistible force over the ridge that retains the lake, and carrying along with it from the bottom of the lake basin as well as from the downward slopes everything that is movable, or that is capable of being broken away by main force. This is how we find that grooves and scratches made on the rocks by land ice are always straight and parallel; and this is also how glaciers came to be the most powerful agent that we know of for breaking, scratching, grinding down, and altering the surface of the country.

Glaciation of Hills and Rocks.

The tops of the high range of hills which form the eastern watershed of the Nairn are rounded and smoothed in such a way as ice only could have done. Weathering by ordinary storms of rain, snow, frost, and wind would only tend to make the tops more jagged and saw-like; for the stratification of the gneiss rocks of which they are composed is nearly in a vertical position in this locality. Several high rocky hills of the district, although smoothed down on the top, are rugged and precipitous on one or more sides. Some of the most notable of these rocks are Creag Ruthven, south of Loch Ruthven; Creag Mòhr of Brin; Stac-an-fhithich, a rock at the east end of Loch Duntelchaig, and Creag-a-chlachan at Dunlichity; and the Dune of Daviot, all composed of gneiss. There are also the following high cliffs of Old Red Conglomerate,—Creag-nan-Clag on the

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Dunchea Hill, Tom-na-h-iolaire between Loch Duntelchaig and Loch Ruthven, and a rocky face behind Meallmòr of Daltullich. The faces of these rocks ranging from 900 to 1300 feet above sea-level did not smooth down under the ice, evidently because they continued to break away from the base, and more especially so, no doubt, during the undermining process applied to their sides by the later glaciers that flowed along the valleys without covering the higher hills. It was such rocks as these that must have furnished the glaciers with the tools and chisels with which they scratched and smoothed the rocks lower down; and they were doubtless the sources of many of the travelled boulders scattered over the country. At the east end of Loch Duntelchaig, amidst a confused heap of splintered rocks, there is one mass as large as a well-sized cottage that has fallen away from the cliff above; and at the conglomerate cliff of Creag-na-h-iolaire, 2 miles farther south, a mass of conglomerate 20 feet high is now standing on its end in the ground just where it fell direct from an overhanging point 80 or 90 feet above it. Another long piece fell lately on its end at the same spot, but did not quite succeed in standing on its head. If these masses of rock had fallen on the edge of the ancient glacier they would have been carried down the country.

Ice Scratches on Hills.

The following are the directions of some of the ice grooves on rocks above the height of 1000 feet, indicating the direction from which the ice-sheet advanced. Rock near the top of Beinn-Bheurlaich from due south. On a rock, Creagan-bad-each, above Mid Lairg, 1100 feet above the sea, the ice came from S. 10° W., and on the Meall-mòr rock, three quarters of a mile east of the Free Church, 1200 feet above the sea, from S. 20° E. On the rock last mentioned there is a remarkably distinct groove that can be traced for 20 or 25 feet. Indeed it may be longer than this, for the lower end of it disappears under the soil. This is the most distinct groove that I have yet met with in the strath. These grooves seem to indicate that the first great ice-sheet proceeded from the central region of the Monadh-Liath mountains, where the rivers Nairn, Findhorn, Farigag, and Foyers originate.

Roches Moutonnées and Ice Grooves on Low Grounds.

In the flat grounds of the strath there are many *Roches moutonnées*, which are rounded and smoothed on the upper end, and rugged and abrupt at the end next to the sea. Of these there are good specimens at Craggie in the flat ground below Lairgintour, at Scatrag Farm, and at several points on the flat ground west and south-west of the Free Church of Daviot. Farther up the strath there is one very notable specimen, the

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Torc Rock near Brin. The rounded end of these rocks clearly indicates the direction from which the ice-stream passed over them; and for determining the direction more precisely grooves and scratches can almost always be found by careful examination of the least weathered parts. All these in the flat ground show that the last ice-river followed the windings of the valley.

A few observations of the ice grooves on the low grounds may be noted here:—On a rock at Craggie Inn the ice drift was from S. 20° W.; on rocks below Lairgintour from W. 30° S.; on a rock at the old bridge of Faillie from W. 22° S.; on rocks south of the river opposite Beachan Farm from S. 7° W.; and on rocks west of the Free Church of Daviot from S. 3° W.

Boulder Clay.

In the upper part of the valley the boulder-clay is principally found on the east side of the river.

The highest point at which it appears is on the face of Carn Ghriogair, near the source of the Nairn, at from 1700 to 1800 feet above the sea, where deep sections of it are to be seen, cut through by the stream. It is also found in almost all the tributary streams of the eastern slope from Aberarder to Clava, up to heights varying from 1000 to 1600 feet. But there are no streams on the western slope on which such elevated masses of the clay can be found; and even the lower accumulations of the till are not to be found on the west side of the valley at any point west of Faillie, which is about 2 miles above Daviot. Of the lower masses of boulder-clay left in the sides of the valley by the smaller glacier that followed the windings of the river, the principal ones on the east side are from Wester Lairgs to Craggie, from Daltullich to Cantraydown, and from Cawdor to Geddes; and on the west side from Faillie to Daviot, and from Nairnside to Clephanton. From Daviot and Craggie westward, these masses of the clay are covered with masses of the upper gravelly tills, sand, and large boulders, which are not found in any considerable quantities east of Daviot, except near the mouth of the river. It is remarkable that conglomerate and sandstone boulders are to be found in the boulder-clay of the Craggie Burn, miles beyond the present limit of the sandstone, and also outside the line of drift passing over the sandstone area, and up to the watershed about 900 feet high at Lochan-a-chaorainn; indeed such stones are more numerous at this height than in the lower end of this burn. Sandstone boulders are also found in the Mid Lairg Burn up to a similar height, and in a mass of boulder clay at Lynemore near Loch Moy at a height of 1100 feet. From Daviot and Craggie westward the lower till is friable and stony. But from Daviot towards the sea it gradually increases in hardness and tenacity. (The great line of moraine clay found along

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the foot of the northern slope of the Drumashie ridge, passing 2 miles from Inverness, is still harder, and there is a considerable quantity of good brick clay in the low flat ground near the Culloden Railway Station, which is manufactured at the Culloden Brick Works into excellent bricks and drain pipes.)

Upper Till and Gravels.

The gravel and sand which form the surface of the irregular terraces and ridges, on each side of the river, above Daviot range from the level of the river to between 250 and 300 feet above it. The first idea which I formed of those terraces was that they were the remains of larger masses of gravel and sand deposited in an ancient lake that filled the strath to the west of Daviot. A more careful examination of the ground has, however, dispelled that idea. These gravels as a rule are not stratified, and although they are in a marked degree free from the masses of rough boulders found in great numbers on the surrounding moors, still there are some large boulders on the surface of the terraces, and a few boulders, some of immense size, deeply embedded in them.

Lateral Moraines.

There are three narrow zig-zag ridges of gravel, about a mile in length, on the top of the irregular gravel terraces at Mid Lairg and Wester Lairg, which, although consisting of water-worn gravel, I conclude to be lateral moraines. These ridges stand from 20 to 40 feet above the general level of the terrace, and are much steeper in the sides than the slope which gravel takes under water subject to the action of waves. Their slopes are 1 foot vertical to from 2 to 3 feet horizontal, while the slope of such gravel in the edge of the sea or of a lake would be 1 vertical to 5 or 6 horizontal. And, besides, these ridges are for considerable distances sharp and narrow on the top, just as they might be expected to be left by the decaying edge of the glacier with but slight marks of smoothing down or of stratification by the flood-waters along the side of the ice. These facts do not seem reconcilable with the lake theory, and it is therefore concluded that the gravel was collected by the ice, and either dropped over the edges of, or pushed aside by, the last glaciers, in the form of the narrow ridges as we now find them.

To account for the nature and form of these ridges I assume that there was a long period during which a glacier filled the strath to a depth of 250 or 300 feet above the bed of the river, or about the height of its western watershed. Assuming that the glacier was on its final decrease, and that there was a great mass of gravel taken from the mountain slopes between Aberarder and Lairgs lying on its edge, and underneath it in

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the form of a ground moraine the material forming these ridges would be accumulated along the edge of the glacier, and partly stratified by floods at the side of the ice, at the wider part of the valley at Wester Lairg, where we find these ridges. The moraine next to the hill would be first laid down, and then the others nearer the river in succession; for, as I apprehend it, no part of these gravel ridges is a medial moraine in the ordinary sense of the term; nor do they consist of the rough masses of stones usually known as moraines.

A similar explanation, coupled with a still greater action of flood-water flowing along the east side of the glacier and from the adjoining moor, will also apply to the two long gravel ridges with marshy hollows behind them that run parallel with the river, on the east slope of the valley between Daltullich and Cantraydown, at heights varying from 400 to 600 feet above sea-level, or about the same level as the western watershed of the valley in the same locality.

Terminal Moraine, &c.

A ridge of soft shaly gravel called Toman-fad, situated where the road crosses the Gask ridge, 820 feet above the sea, formerly attributed to the action of water, is, in my opinion, a terminal moraine. It is remarkable that this and one other point are the only places in the district where shaly gravel can be seen. The other point is at the side of the district road a quarter of a mile east of the farm house of Faillie. A series of artificial-looking gravelly hummocks, at about the same height on the moor of Faillie, must also be fragments of terminal moraine matter left by the first great ice-sheet when in a state of decay. And there are also, near the same place, two remarkable hollows crossing the flat moor above Faillie which also appear to me to have been formed at the same time by flood-water pouring off the end of the glacier. It is remarkable that these are almost the only traces of terminal moraines—apart from the flocks of scattered boulders—which can be found in the valley,—unless the gravelly ridges at Raitloan, Kildrummie, &c., near the town of Nairn, can be so described, which seems rather doubtful. The moraine ridges and banks at the foot of the northern slope of the Drumashie ridge from near Culloden to Kildrummie must, I think, be considered as the lateral ground-moraine of the greater glacier which issued from the Loch Ness valley.

Sandy Deposits.

Between Daviot House and the old bridge of Faillie there are interrupted shelves and knolls of considerable size, which consist almost entirely of fine sand. At first sight they appear to be disconnected parts of an ancient lake terrace. The levels are,

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however, so irregular, and their forms and positions, indeed, altogether so inconsistent with the idea of their being lake terraces or deltas, that I have been induced to look elsewhere for their origin. They are principally found on the west or north side of the river. The conclusion I have come to is that the sand was accumulated during the time of the later glaciers, when the narrow gorge at Daviot House would be choked up with the ice, and when the wider part of the valley immediately west of Daviot would have a great mass of ice in the middle with an accumulation of flood-water on each side of it. At the same time the valley of the Findhorn would also be similarly occupied by glaciers, and great floods of water coming from the melting ice and snow. A narrow gorge commencing at Pollochaig, 2½ or 3 miles east of Freeburn, and extending downwards for several miles, would be blocked up with ice and moraine matter, and the floods of the Findhorn valley accumulating above this neck would be diverted towards the Nairn by the way of Loch Moy and Craggie. The watershed between Craggie and Moy is about 920 feet above the sea; and a barrier of 80 or 90 feet in height at the narrow gorge on the Findhorn would send its waters over the ridge to Craggie. Such floods from the Findhorn would carry immense quantities of fine sand into the Nairn valley and deposit it in irregular masses on both sides of the flooded glacier, at and above Daviot as we find it. In connection with this theory it may be mentioned that there is also a great mass of sand at the Craggie Burn, near the watershed between Craggie and Moy just mentioned.

Travelled Boulders.

There are great numbers of travelled or carried boulders found in all parts of the strath, from the lowest point up to 1800 feet, if not higher. A few of those on high points may be mentioned.

On the top of Tom-na-h-iolaire, or Creag Dhearg, the conglomerate summit, about 1200 feet high, between Loch Duntelchaig and Loch Ruthven, there are ten or eleven granite and gneiss blocks from 3 to 4 feet in diameter lying on and around the very summit. There are others at a similar height on the top between the Loch-a-Chlachan and Brin. On the west side of Creag-a-Chlachan, above Dunlichity church, a hill itself consisting of gneiss, there are to be seen numerous pieces of dark brown sandstone flags carried up from the Loch Duntelchaig basin, and also bits of a great dyke of red porphyry on the south side of that loch scattered from the base up to 1190 feet. On Beinn-a-Bheurlaich, above Mid Lairg, there are rounded granite and gneiss blocks lying in the smoothed gneiss and granite rocks at 1550 feet; the same on Creag-nan-eoin farther south at 1500 feet; and on the summit of Beinn-nan-

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Cailleach still farther south are three large boulders at a height of 1800, and also on Meall-mòr above Inverarnie several granite and gneiss boulders at 1200 feet, and a granite boulder on the summit of the conglomerate of Meall-mòr of Daltullich also at 1200 feet. These appear to have in some cases been pushed along the ground under the glacier, and in other cases to have dropped off the melting ice when the great ice-sheet in a decaying state came to a stand on the higher summits.

Space will not permit of an attempt to trace the several classes of boulders to their parent rocks; but it may be remarked that, with a few interesting exceptions unaccounted for, they are found to be carried in a north-easterly direction. Several distinct classes of boulders are represented in the district.

1. There are jointed stones which have moved only a few inches or feet from their original position. Remarkable specimens of this class are seen at the back of the Dune of Daviot and on the moor of Faillie.

2. Rough and angular stones pushed for a distance along the ground, and forming a stream of blocks for a considerable distance from the quarry. A notable instance of this can be seen in the mass of conglomerate boulders above Faillie, dragged to all distances towards Daviot.

3. Rough and angular wanderers dropped down singly, far from their original site, of which there are instances in many places.

4. Rounded and water-worn boulders, whose origin it is generally more difficult to determine.

5. Perched blocks, sometimes round and sometimes angular, which have been let down on the most extraordinary spots,—the rounded summit of a rock, the verge of a precipice, or perhaps the point of an inaccessible rock. One of these on the top of the hill above Achavaneran Farm is balanced on a narrow pinnacle of rock about 20 feet high.

6. Split boulders that appear to have fallen from such a height as to have been broken into two or more pieces where they fell. Of this class there are numerous instances throughout the district and neighbourhood known by the Gaelic name, *Clach-Sgoilte* (or the split stone). This class is generally of a large size.

Remarkable Boulders.

There are a few notable specimens of travelled boulders that may be worth special mention.

The Tomriach stone (the stone of the grey hill), measuring 27′ × 22′ × 15′, is an angular mass of conglomerate lying on the east of the river, on gneiss rock, at a height of 400 feet above sea-level, and weighing from 500 to 600 tons. From the liver-coloured pebbles contained in it, this stone is generally supposed to have come from the conglomerate at Achnabat, or Loch Ceiglais

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(15 miles W. 40° S. of its present position). But it is difficult to see how the directions of the ice-drift, so far as known from the marks on the rocks at least, could have brought it from there to its present position on the east side of the river. It seems to me, however, that its origin may be sought for at a nearer point, where rocks of nearly the same composition are to be found, especially as it appears to belong to the east, or to a medial moraine of the last Nairn valley glacier. A split conglomerate boulder of considerable size (11′ × 6′ × 5′), and of nearly the same composition, is found in the burn below Mid Lairg Farm, and more than half a mile outside the conglomerate so far as at present determined. It is the only one of its kind in the place; and no ice-current that we know of by the ice marks could bring it there from the masses of conglomerate at Loch Ceiglais or Loch Duntelchaig.

Clach-a-nid (the stone of the nest) is an immense boulder of gneiss weighing over 500 tons, and lying at a height of 950 feet above the sea, on the east shoulder of the hill of Daltullich. It lies in a nest or slight hollow in the soil, and hence probably its name.

Clach-na-h-ulaidh (the stone of the hidden treasure) is a perched block of gneiss below Daltullich Farm, resting on shaly sandstone, and balanced on two sharp points of itself and on a decaying bit of shale rock.

Clach-an-Fhreiceadain (the sentinel stone), also called Clach-na-Faire (the stone of the watching), is a perched block of gneiss on the east end of Creag-a-Chlachan, above Dunlichity church. It, too, is balanced on the bare rock, on two sharp points of its own edge and a small stone, just in the same way as Clach-na-h-ulaidh. The name of this stone is derived from the old custom of posting a watchman at it during times of clan disturbance to spy out the direction taken by an invading or cattle-lifting clan, while the men of the strath were being gathered for defence or pursuit.

One more giant stone and the list must be closed, although by no means exhausted

The Brownie stone is an immense block of conglomerate (25′ × 18′ × 10′) weighing about 300 tons, lying on the Drumashie ridge, in the parish boundary, half a mile east of Bunachton. Connected with it there is a mythical story which relates that one of Fingal's heroes, during their sports, threw it from the (conglomerate) top of Dunean Hill, beyond the River Ness, saying, as he took it up, "I will throw this little one first." What he threw next does not appear. Another, and apparently more modern version of the story relates that two Brownies or giants of the fairy race were standing one on the spot where the Brownie stone is now seen, and the other on the east side of

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Loch Bunachton, where lies another conglomerate boulder nearly equal in bulk to the Brownie stone. For some cause unknown, the two giants began pelting one another with stones, the smallest of which, as seen on the ground to this day, were many tons in weight. The giant on the east side of the loch threw the Brownie stone, but missed his mark; while he on the west side threw the stone now lying east of the loch and killed his man, and that stone is to this day called Clach-an-duine-mhairbh (the stone of the dead man).

But the Brownie stone is also connected with a real tragedy of later times. The chief of the clan Mackintosh was beheaded by some treachery, while on a visit to Castle Gordon. The heir was a mere babe; and the faithful leaders of the clan held counsel together and resolved to put him into safe hiding until he should be old enough to act for himself,—and the mother, even, was not to know of his hiding-place, in case, in her over-anxiety, the secret should be revealed. The person appointed to carry away the child was instructed to stand on one side of the Brownie stone, and to listen to what he should hear, but to speak to no one. Another person bringing the child to the opposite side, and addressing himself to the stone, gave the necessary directions, and left the child. The young chief was reared in safety and in perfect secrecy, and at no great distance from the stone, too, and lived to be chief of the clan. It is a proverb among Highlanders that secrets are to be told to the stones. Hence perhaps the idea of addressing the secret directions to the stone in this case. The story reminds one of the affecting Bible scene when Jonathan warned David to flee from Saul, by words addressed to the youth who collected his arrows at the stone (or, "this heap of stones") Ezel, where David lay in hiding.

I hope what I have stated so imperfectly will induce some more skilful and experienced geologists to examine the ground I have gone over, and to write the result; and if so, my attempt at stating the problem of the glacial drift of Strathnairn will not be altogether without fruit.

Note.—Since the above paper went to press the author has found an extensive boulder-clay bed at Clava, which has yielded many shells, including *Leda pernula*, *Littorina litorea*, *Tellina Balthica*, and some Foraminifera. The bed is at an elevation of 500 feet. The author is engaged in the investigation of this interesting bed, and will communicate the results to the Society early next session.

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VII.—*Notes on Maulmain and Neighbourhood.*

By R. ROMANIS, D.Sc.

(Read 17th February 1881.)

Maulmain stands on the Salween, about 20 miles from the sea, at the confluence of the rivers Gyne and Attaran. The influence of the tide is observed for 40 miles above Maulmain. The country is an alluvial plain from which rise numerous precipitous limestone rocks with many caves, and hollowed at the base by the action of the sea.

The rocks near Maulmain are crystalline, with a few doubtful traces of fossils, but at the Duke of York's Nose, a remarkable mountain about 40 miles from Maulmain, I observed some very beautiful Brachiopoda and Polyzoa. These limestones belong to the Carboniferous period. Here also I noticed a rock about 200 feet high shaped like an hour-glass, rising abruptly from the plain about 2 miles from the chain of limestone hills of which the Duke of York's Nose forms a part. This alluvial plain has been formed almost within historical times, but I am inclined to think that it is older than that of Regu; the vegetation is more varied, as well as the fauna. One point that struck me at once was the number of land shells; the rice-fields are covered with them, they consist of species of Conovulus and Cyclostoma and others that I did not determine. At Rangoon I have only found a large Cyclostoma on the laterite ridge, but mollusca without shells are pretty common. This may be due to the extremely small quantity of lime in the soil about Rangoon, in the samples I have analysed it seldom reaches one-tenth of 1 per cent.

Maulmain is remarkable for the number of hot springs in the neighbourhood. I made an analysis of a small sample of one of these from Belongzoon or Ogre's Island opposite Maulmain. It is a pool about 4 yards in diameter, and from 3 to 4 feet deep; gas is constantly bubbling through it. Its temperature is about 130° Fahr. Its composition most nearly resembles that of the Harrowgate water, except that it does not contain unoxydised sulphur. Sp. gr., 1010·3; temp., 130° Fahr.

	Grammes per litre.
$CaCl_2$	2·218
$MgCl_2$	0·885
$NaCl$	10·446
KCl	0·344
$CaCO_3$	0·175
Fe_2O_3	0·002
SO_3	0·109
	14·179

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An important point in connection with tropical waters is the comparatively large amount of silica they contain in a soluble form. This has also been observed in America. It shows the decomposition of felspathic rocks proceeds faster when the temperature is high, and thus we cannot argue from the present rate of decomposition in temperate regions to what it was when the temperature was higher, as in the interglacial periods. No doubt the property which laterite has, of hardening when exposed to the air, is due to the soluble silica dissolved in the water which permeates it passing into the insoluble form and binding the grains of sand together.

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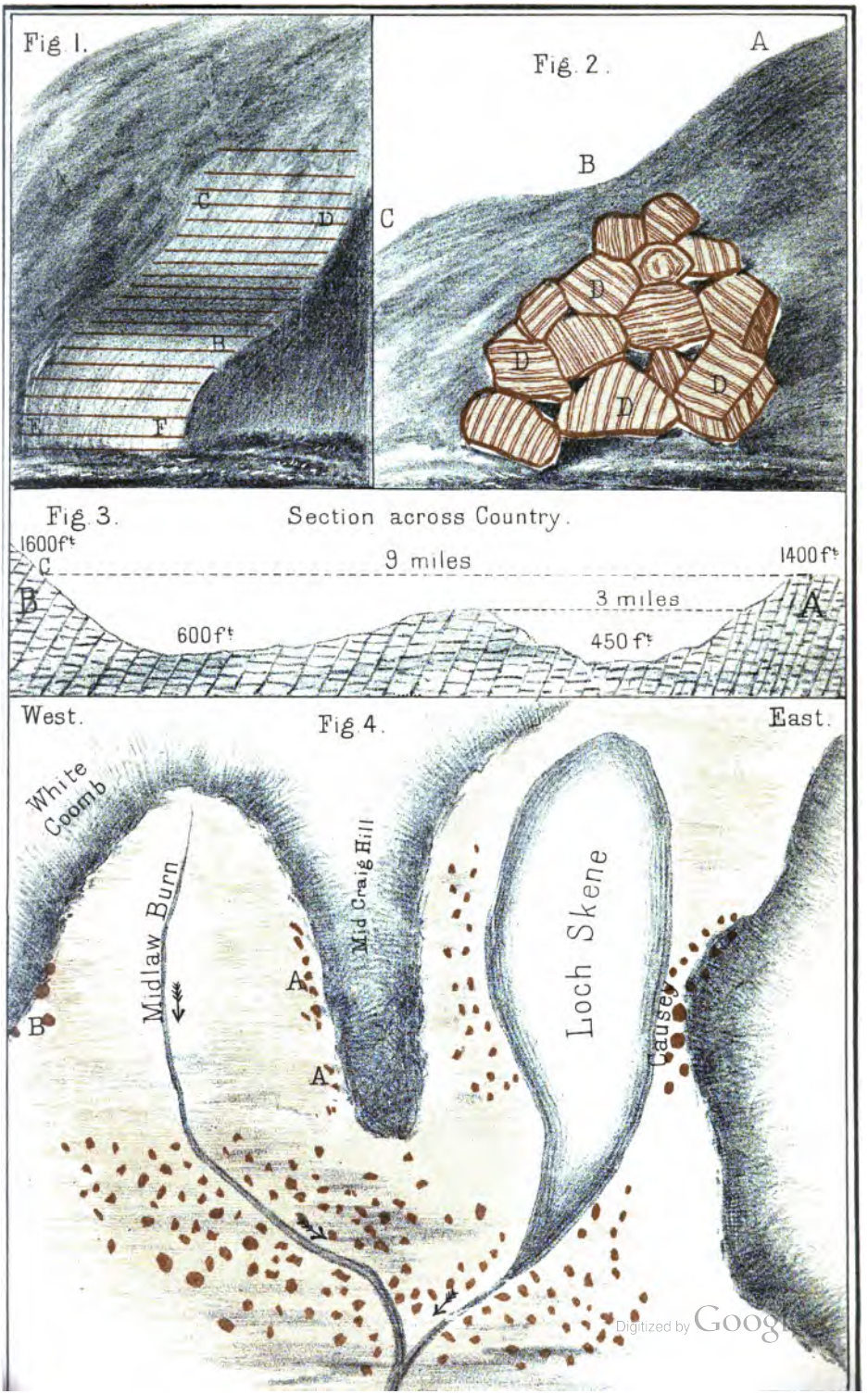

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VIII.—*Notes from a Diary in* 1862 *by* D. MILNE HOME, LL.D., *of some Geological Observations made* (1) *at points along the line of Caledonian Railway from Carstairs southwards,* (2) *at Moffat, and* (3) *at Loch Skene.*

(Read 17th March 1881.)

(1.) *Caledonian Railway.*

1. In the *Carstairs, district* enormous accumulations of sand occur, forming beds stratified in layers nearly horizontal. Some of the sections exposed are from 60 to 70 feet deep. In several of these, many pebbles, including lumps of coal, the largest about the size of a man's head. These so rounded as to indicate that they have undergone much friction *in transitu.* These sand deposits seem to rest on boulder-clay, a small patch of which is seen in a stream at one place adjoining. The district, covered by these deposits, comprises several square miles, and is on a pretty uniform level of about 700 feet above the sea. They occasionally form mounds and elongated ridges, which may be due either to original formation or to subsequent denudation. If originally deposited in the sea the sediment composing them would be laid down as submarine banks; or by the action of currents, they may have acquired the forms they now exhibit.

To the north of Carstairs village there are some long ridges of gravel, tolerably free from sand, and consisting of well-rounded pebbles and occasional boulders. The pebbles do not form regularly stratified beds. Though most of those gravelly deposits run in a direction east and west, some follow a sinuous line and even unite with others, so as to contain small lakes or pools of water.

The ridge enclosing one of these lakelets had been cut through to drain it, and thus a good opportunity was afforded of examining the materials, and the way in which these were arranged. In one of these gravel ridges there was seen a pretty large boulder in the heart of a mass of sand. It seemed as if the boulder had been dropped into the bed of sand.

These gravel deposits were undoubtedly due to the action of water.

The pebbles were chiefly sandstone, shale, limestone, and coal, all capable of being easily moved by a current of water.

I observe that the late Robert Chambers says of this Carstairs district, that it is "an elevated plateau crowned with diluvium sand and gravel. The memorials of the sea are striking. The plateau is composed of a deep bed of sand and gravel, consisting of prominent portions of large extent. The road from Lanark to Biggar crosses one of these flat tracks, which has been converted into a race course. Between Carstairs and Carnwath, it is backed by a ridge of sandhills" ("Old Sea Margins," p. 213).

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2. In passing up the valley of the Clyde by railway, I noticed near Abingdon and Elvanfoot, several long ridges of boulder-clay which I regretted not having had an opportunity of examining, as they seemed interesting, from the number of boulders standing on and projecting out of them.

3. The next spot visited was the celebrated quarry of Old Red Sandstone on Corncockle Muir, where the footprints of animals were traceable on the stone flags. The rocks are well covered by boulder-clay, over which lies a deposit of gravel. The rocks are smoothed across their upturned edges, evidently by the passage over them of the boulder-clay, and of the numerous pebbles interspersed in it, consisting of hard Silurian and some porphyritic pebbles, most probably derived from hills to the north. The colour of the boulder-clay was reddish, derived no doubt from the abrasion of the Red Sandstone rocks over which the clay had been pushed.

Though I observed no rock striations, I found pebbles in the boulder-clay with striæ, their directions being as usual parallel with the longer axis of the pebble. The elongated pebbles lay with the axis about north and south, which is the general line of the valley at that place.

(2.) *Moffat.*

I proceeded up to the Mineral Well, and to a steep rocky hill (to the north of the Well), known as the *Common Craig*—so called, because the inhabitants have by custom a right of quarrying stones from the hill.

On reaching the hill, and proceeding round its western steep slopes, I noticed several spots of much interest.

The first thing which attracted my attention was a part of the hard slate rock of the hill beautifully smoothed and striated. Fig. 1 represents it—The part A B E F is almost verticle, as if much worn by excessive friction. The part above (A B C D) sloped upwards; evidently the hill at this spot had originally projected beyond the general surface, and on this account had sustained more abrasion.

The smoothed surface in fig. 1 fronted about due west. The direction of the striæ was about due north (magnetic).

At another spot on the same north-west shoulder of the *Common Craig hill,* I found a rock surface sloping down towards north-north-west at a small angle; striæ were on it running in a direction north by east, *and rising on the smoothed surface towards south by west, at an angle of* 10° *or* 12°. To produce striæ rising in that direction on a rock surface dipping north-north-west, the striating agent must have come from north by west, and have risen upwards in its progress south, so as to get past the shoulder of the hill.

On a minute examination of the hill, I found that there were

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other smoothed and striated rocks facing various points between west-north-west and north-north-west, but that there were none facing any point to the south of west-north-west. At the most southern point, the striæ, instead of being horizontal, *sloped down towards the south* at an angle of about 10°, showing that the striating agent after passing up over the projecting shoulder of the hill, began to follow a downward course, in unison with the present slope of the valley, to the south.

At one place, a little to the south of these smoothed rocks, I found a great accumulation of boulders. They were on the south side of a projecting rock A B C (fig. 2). They had come from the north, and had been tumbled over the rock towards the south, and were lying at the base of the rock, viz., D D D.

There is more than one place where boulders had accumulated on the south side of a rocky knoll or a projecting shoulder of the hill. At these places, there probably had been considerable pressure on the hill by the same agent, whatever it was, which brought the boulders and smoothed the rocks.

That agent had apparently come from the north, for the angles of the rock in the hill, which project towards the north and the west, are well rounded, whilst those projecting towards the south-west and south are rough.

These smoothed and striated rocks are not apparent at a higher level than about 1300 feet above the sea (assuming Moffat to be 360 feet); they are most abundantly smoothed at a height of about 1050 feet.

What was the striating agent which thus acted so violently on the north-west shoulder of the *Common Craig hill*, I was not able to ascertain. If a glacier moved down the valley and pressed on the rocks of the hill, where had it been formed? *Hart Fell* is the highest mountain of this district, and reaches to a height of 2422 feet above the sea, and bears about east-north-east from the *Common Craig*, at a distance of 7 miles. I did not visit *Hart Fell*. But the contours of the ordnance map don't show any hollow or valley suited to the formation of a glacier, high enough to flow down upon the Common Craig, whose smoothed and striated surfaces are only about 1000 feet below the very top of Hart Fell.

If a glacier came from *Hart Fell*, it would more naturally flow down the valley situated to the west of the Common Craig, as shown on fig. 3, where A is the Common Craig hill, and the gradients of the country are shown along a distance of 9 miles due west from the Common Craig.

The only other theory available, is the supposition of floating ice brought by a sea-current from the north-west, when Scotland was submerged to the extent of about 2000 feet.

To the south-east of the Common Craig there is a valley through which a small stream flows, called in the local map

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"*Well Burn*," and apparently in the Ordnance Map "*Birnock Water*."

On the east side of this valley, at a height of about 1200 feet above the sea, I found an enormous mass of drift materials with large boulders embedded.

I next visited a remarkable hollow in the hills about a mile to the north-west of the Common Craig, called in both maps "the Devil's Beef Tub." This hollow is also full of drift. The lowest part is about 700 feet above the sea, but the enclosing hills reach to a height of 1300 feet.

On a hill not far from Moffat to the east, Frenchland Tower stands at the mouth of a valley which comes down from the north-east. On each side of this valley a plateau or terrace, formed on drift, is distinctly visible at a height of about 750 feet above the sea. The drift is full of large boulders. The terrace on the north side of the valley can be traced (though faintly) towards Moffat Mineral Well. On the north side of this valley there is a range of hills from 1100 to 1600 feet in height, by which it (the valley) would be as it were protected from the agency which moved down the larger (or Common Craig) valley, containing striated rocks and boulders.

On the south slope of the hill, on the north side of this Frenchland valley, there is an enormous accumulation of boulders, mostly angular. If floating ice came down the principal valley from the north-north-west, an eddy may have brought them in here.

Near the top of one of these hills (I regret that I have not marked its name) I found rocks ground down and smoothed at a height of about 900 feet above the sea. There the direction of the striæ was north-east and south-west.

At Craigieburn (about 2 miles east of Moffat on the Selkirk road) the rocks were seen to be smoothed and striated, at a level of about 900 feet above the sea. The direction of the striæ is east-north-east, being the direction of the valley at this place.

I walked from Moffat to Blacklaw Hill, situated to the north-west, about 3 or 4 miles distant. The rock surfaces there show extensive smoothings, indicating a movement of the striating agent from the north or north-east. The height of this hill is about 900 feet above the sea.

(3.) *Loch Skene.*

I next walked towards Loch Skene, going by a hill called Carrifran, about 2400 feet high.

In two of the valleys passed through, I observed great accumulations of drift with embedded boulders rounded. In both valleys there were appearances of terraces at a height of from 1280 to 1310 feet above the sea. The gravel composing these terraces, was rudely stratified.

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On reaching Loch Skene, I found along its eastern side an embankment of drift, which my guide said went by the name of the *Loch Causey* (see fig. 4). It is composed of coarse pebbles of a considerable size, and is about 70 feet above the level of the lake. To the south of the lake there are numberless mounds of gravel, which might have been formed by the action of rain and small streams, out of a large mass of gravel, once more extensive. Large boulders stand on some of the mounds of gravel; these may have originally been embedded in the gravel, and have become exposed by denudation. The west side of Loch Skene consists of a rocky hill called Mid Craig, on which, if I remember correctly, there are some smoothed rocks. This Mid Craig hill forms a spur or ridge between Loch Skene and a valley through which the Midlaw Burn flows. The last-mentioned valley in one part of it has a flat, such as might have been at one time the bottom of a lake. At the south end of this valley, adjoining the general flat district through which Loch Skene discharges itself, there are gravel embankments, which have much the form of moraines. They are now cut through by the Midlaw Burn as it flows onward to join the stream issuing from Loch Skene.

On the east side of this Midlaw Burn valley, at A A, at about 250 feet above its bottom, there is a remarkable ridge of gravel and boulders running on and along the west slope of the Mid Craig hill, having all the appearance of a lateral moraine.

The embankment is about 15 feet high, and runs for nearly 300 yards. It appeared hardly possible to account for it, except on the supposition that detritus had slid down the hill, and had been arrested by ice or by the bed of a lake at the level where the ridge now stands. It runs with such regularity, that at first I thought it might have been the bank of a mill lade, constructed to conduct the Midlaw Burn to a mill.

On the *west* side of this Midlaw valley, and at about the same level as the above-mentioned ridge, there is at the foot of a hill (a spur from the White Coomb) a mass of debris B which may have been washed down and been arrested there by the same cause which formed the embankment on the *east* side. On this west side of the valley there are some smoothed rocks forming surfaces sloping down to the valley at a very steep angle. On these rocks some striæ appear which perplexed me, as some of them are nearly vertical, whilst others are horizontal.

Midlaw Burn valley is about 1900 feet above the level of the sea, and Loch Skene is only about 1700 feet. At first I thought that glaciers had filled each of these valleys, uniting at a point towards the south-west. The mounds of gravel at the mouths of both valleys, I considered might have been moraines. But doubts occurred to me when I considered that each of these valleys was at a very low level to be the birthplace of a glacier,

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and, moreover, being little more than half a mile in length, there would scarcely be sufficient gathering ground for glaciers. Something, however, must have filled the Midlaw valley which had the effect of forming accumulations of drift on both sides, at the height of about 250 feet above the present bottom of the valley.

There might be a possibility of both valleys having at one time been filled with water, with blockage towards the south. The lake in Midlaw valley may have been drained, by the stream from it cutting through the gravel beds at the south end. The occurrence of the "*causey*" on the east bank of Loch Skene was probably formed by detritus sliding down the hill side when the lake stood 70 feet above its present level. *This* subsidence *must* have been caused by its blockage having been cut through.

In two of the valleys passed through on my way to Loch Skene, I fell in with several large boulders. They happened oddly to occupy the same level, though not near one another, viz., about 1800 feet above the sea.

In continuing my walk eastward towards Birkhill on the Selkirk road, I passed over table-land, with rocks greatly smoothed at a height of about 2000 feet. Here there could have been no glacier of any ordinary kind. If it was land ice, it must have been either a great ice-sheet, as suggested by some geologists, or else floating ice.

The smoothing of the rocks and the transport of boulders at the Common Craig certainly cannot be attributed to a glacier, the valley there being much too wide (viz., 3 miles), for any glacier.

The foregoing notes I deferred making use of at the time they were written, viz., in the year 1862, because I was unable to think of any satisfactory explanation of the phenomena. But the paper recently read in this Society by Mr Ralph Richardson on Loch Skene, has induced me to throw these old notes into shape. They are, I admit, very desultory. But it is most unlikely that I will ever again revisit the district, and I give these notes in the hope that other geologists who visit the locality may find some help from the information I now present to the Society.

I am reluctant to offer any explanation, as, till the district has been more extensively examined, sufficient basis for such cannot be obtained. I would only venture to observe, that when these deposits of gravel, sand, and clay were laid down, and boulders transported, Scotland was almost certainly submerged beneath the ocean at least 2000 feet;—that there are many things tending to show, that an arctic temperature then prevailed, caused by a current from the polar regions;—and that as the land emerged slowly from the sea, floating ice may have had something to do in producing the arrangements which I have been describing.

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IX.—*Notes on a few Natural History Collections visited in the course of a Tour on the Continent in* 1880.* By THOMAS STOCK, Natural History Department, Museum of Science and Art, Edinburgh.

(Read 17th March 1881.)

Brussels.—At Brussels the chief national collections are housed in a continuous range of buildings, which is a convenient arrangement for visitors. The natural history objects have considerable space allotted to them in long but not well-lighted galleries. The fittings are neat throughout, of simple Gothic design, and of unvarnished oak. The recent vertebrata are arranged with taste and skill, and the space is made the most of. The birds are well stuffed. The register number is placed on the label. Maps of distribution are freely exhibited. The nests and eggs are placed in glass trays beside the birds. The fossils are arranged in upright cases which are placed in series behind and slightly raised above each other. Each case has six shelves sloping to the front. The fossils are placed loose in trays and labelled (too sparingly) in manuscript. There is room for improvement both in the scientific arrangement and in the methods of mounting employed. Everything is sacrificed to the wants of the stratigraphical geologist. The museum is not rich in Palæozoic fossils; but there is a good representation from the Belgian Tertiaries. The numerous subdivisions of the Tertiary rocks, with their long series of fossils, make the study of any particular zoological group exceedingly difficult and perplexing. A neat method of mounting certain objects is worthy of remark. Small watch-glasses are cemented together enclosing the object, and fixed on tablets. This method might be adopted with advantage in certain cases, but is not capable of a wide application. Another method is deserving of mention. Fragile Tertiary fossils frequently occur in a sandy matrix. The application of a liquid cement would destroy them. The difficulty is met by imbedding them. Gutta-percha is used here for this purpose; but paraffin would perhaps be better.

* I have much pleasure in acknowledging the assistance I have received in preparing these notes from my colleagues. My friend Mr Clark accompanied me on the journey, and I am indebted to him in a special way for many references and suggestions. Dr Hænsler, formerly assistant at the Polytechnicum Museum of Zürich, has rendered me invaluable help in the part relating to Switzerland. He has supplied me with the majority of the most important facts relating to the museums of that country, and has added to his kindness by revising my manuscript, so that, thanks to him, I have been able to give a trustworthy account of the chief natural history collections of Switzerland.

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In the summer of 1880 the visitor to Brussels enjoyed opportunities of inspecting collections which are not usually exhibited to the public, for in that year was held the National Exhibition commemorating the jubilee of Belgian independence. In it there was a good display of that part of the scientific wealth of the country which was capable of effective exhibition. The extensive semi-public and private collections in various departments of science vied in interest with those of the establishments permanently maintained in the capital. There appeared to be a serious attempt made on the part of the universities, learned bodies, and private collectors to bring together as full a representation of the organic life of the past and present of the country as was possible within the limits of space assigned to them for that purpose. The collections made by private persons were especially deserving of note, and in particular departments were superior to those contained in the majority of public museums. A public museum rarely has money enough to purchase the larger collections as they appear from time to time in the market; its funds usually have to be expended upon specimens belonging to every class of the animal kingdom, and the fact of its being known to possess a revenue at all (the amount of it is exaggerated in popular estimation) has the effect of stinting private beneficence. It is perhaps worth while to publish a list * of the chief contributors to this department of the exhibition. It will serve as a nearly complete record of the chief learned societies and private collections of Belgium (which is not elsewhere easily procurable), and it will also show in what spirit and by what means both societies and private individuals worked together to make their department of the exhibition a success.

Université libre de Bruxelles. Exhibited under nine heads. Models, charts, scientific apparatus, books, &c.

Université catholique de Louvain. Publications.

Université de Gand. Exhibits from the faculties of science and medicine. Scientific apparatus, anatomical preparations. Under the latter head was a series of interesting specimens prepared by freezing and preserved dry by the application of a new glycerine method. Model of a laboratory table. Microscopic preparations, photographs, books.

Féderation médicale belge. Publications.

École de médecine vétérinaire de l'État, à Cureghem-Anderlicht. Pathological and anatomical preparations.

École d'horticulture de l'État à Gand. Herbarium of indigenous plants. Models of different methods of grafting. Preparations by students.

* Arranged from the official catalogue.

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Jardin botanique de l'État à Bruxelles. Vegetable products. A series of Belgian Coal-measure plants, &c.

Institut agricole de l'État à Gembloux. Diagrams, publications, &c.

Union agricole et horticole de Forest à Forest-lez-Bruxelles. Herbarium of Belgian flora. Insects of Belgium. Woods. Fossils, &c.

Société entomologique de Belgique à Liége. Publications. Entomological diagrams and plates, &c.

Société géologique de Belgique à Liége. A collection of Belgian minerals sent by the University of Liége, MM. De Koninck, Dewalque, and others.

Société belge de microscopie à Ixelles. Publications. Microscopes, objects, accessories, &c. Members of this society also exhibited separately microscopic preparations, &c., &c., a large and interesting collection.

Cercle Hutois des sciences et des Beaux-Arts à Huy. Publications.

Société malacologique de Belgique à Bruxelles. Twenty-five members of this society exhibited separate collections. The following were the most important:—

Colbeau, J. Quarternary fossils of Belgium.

Crocq, D. J. (President). Fossils of the "système Bruxellien" from Woluwe-St-Lambert.

De la Fontaine, J. Fossils from the neighbourhood of Gand.

De Looz-Corswarem, Count Georges. Fossils from the "système heersien" of Gelinden, plants, molluscs, and fishes. Fossils from the "système tongrien" of Le Neerepen and of Vliermael. Fossils from the "système hervien" of Hosden.

Hallez, P. Fossils from the Belgian Tertiaries. Genera of recent shells.

Lambotte, E. Anatomical preparations of mollusca.

Lefèvre, T. *Halitherium.* Tertiary fossils.

Malaise, C. H. G. L. Belgian Camb., Silur., Dev., and Jurass. fossils.

Piret, A. Carb., Jurass., Cret., and Tert. fossils of Belgium.

De Ladrière, P. Fossils of Brussels and neighbourhood.

Purves, J. C., Dr. Shells from the Antilles, Devonian fossils from the Ardennes. A good collection.

Roffiaen, H. Cret. fossils of Brabant.

Rutot, A. Eoc. fossils of Belgium, "système heersien, landenien, ypresien, paniselien, bruxellien, laekenien, and wemmelien."

Van den Broeck, E. Plioc. shells from Antwerp.

Pelseneer, P. Marine shells of Belgium.

Denis. H. Jurass. fossils from Jamoigne.

Société royale de pharmacie de Bruxelles. Photographic herbarium, &c.

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Société royale des sciences médicales et naturelles de Bruxelles. Instruments, publications, &c.

Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique. Publications.

Société belge de géographie. Bulletin.

Société de Pharmacie à Anvers. Its Journal.

Société Archéologique de Charleroi. Ancient pottery, &c.

Société Archéologique de Nivelles. Publications, collections, instruments.

Société Royale de médicine publique à Bruxelles. Publications, &c.

Société Royale Linnéenne à Bruxelles. Bulletin, &c.

Société médico-chirurgicale de Liége, à Liége. Annals.

Société Royale des Sciences à Liége. Memoirs.

Bonn.—The Natural History Museum of the University of Bonn is situated in an old building at the end of the Poppelsdorfee Allée. Under the direction of Professor Troschel and his predecessors upwards of 160,000 specimens have been gathered together. In fossils it is of course richest in those that have been collected from the Devonian rocks of the Eifel and the Siebengebirge. A fine series of *Archægosaurus* remains was noticeable, and the fishes from Reichelsdorf are interesting. One hall is got up in the form of a grotto, and produces a bizarre effect. Nothing of much service was learnt from the exhibition point of view. The casing is antiquated and the light defective. The material, however, is abundant and good, and of great use to students of special departments of science. Here, as elsewhere, the courtesy of the officials was noteworthy, and Professor Troschel put himself to much trouble to gratify us with a sight of some specimens of which we were in quest.

Switzerland.—The numerous museums of Switzerland may be classed under two heads: (1) the cantonal and district (*Bezirk*) museums, and (2) the museums supported by the state, municipalities, and universities.

1. *The Cantonal and District Museums* are of very unequal importance. The larger and richer cantons have museums attached to their schools (the *Cantonsschulen*, which include *Gymnasia* and *Gewerbeschulen*), but they contribute very little to their support beyond providing room for the specimens, and small salaries to the officers responsible for their safe keeping. As a consequence, the larger and often the more valuable part of the collections is stowed away in passages and cellars, while exhibition space is found only for those objects which are absolutely necessary for the carrying on of the scientific work of the schools. Some of these local museums, situated in very productive districts, have accumulated a large amount of scientific material which yet awaits the attention of investigators.

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Permission would no doubt be accorded, in most cases, to the worker who wished to examine it, but his examination, in default of good light and space, would be attended with difficulty. These collections are mainly due to the activity of the members of the local natural history societies. The museum being an official institution, and being usually officered by one or more persons of eminence in science, has succeeded in gathering around it those living in the district who are given to scientific research. As a rule, the societies, though numerous, are weak, and they are rarely in possession of sufficient funds to enable them to purchase either the books or the specimens which, removed as they are from the larger towns, they require; and very few indeed are able to publish their own transactions. Many of their members, however, do much good work, and their best papers find their way to the quarterly journal of the *Schweizerische Naturforschende Gesellschaft*, which is the official organ (I believe) of the natural history societies of German Switzerland. In 1876 the following cantons had their own natural history societies:—Aargau, Bâle, Berne, Freiburg, St Gallen, Geneva, Graubünden, Waadt, Lucerne, Neuchâtel, Schaffhausen, Solothurn, Thurgau, and Zürich. The museums of the cantonal schools of Solothurn, Pruntrut, Glarus, and Berne are perhaps the best worth visiting. The collections of the gymnasium of Aarau, too, are important. The district schools (*Bezirksschulen*), the advanced schools (*Fortbildungsschulen*), and the secondary schools (*Secundärschulen*) have often very good collections.

2. *The Museums supported by the State and Large Towns.*—The museums in the larger towns are generally connected with the universities, and are officered for the most part by the professorial staff. There is a director and several curators. The latter are attached to particular departments, of which they make a specialty. Their salaries are low, averaging perhaps £80 per annum; but they usually hold at the same time more lucrative professorial or other appointments.

Berne has a good mineralogical collection. Bâle is rich in Keuper plants, Schaffhausen in Jurassic fossils, and Neuchâtel has a splendid series of Lower Cretaceous forms.

It would be obviously inexpedient to go very fully into the arrangements adopted at all of the larger museums. It will be enough to mention two or three of those which, from the excellence of their arrangements, or from the extent and value of their collections, deserve more extended remark.

Zürich.—The museums of Zürich rank with the best in the country. As a city, Zürich is the centre of the intellectual activity of German Switzerland, and its public museums are of an importance commensurate with that fact. None of the

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museums apparently either at Zürich or elsewhere publish guides to their collections; but the visitor to Switzerland who has provided himself with Heer's "Primeval World of Switzerland" and Keller's "Lake Dwellings," will find in these works the aid he requires to visit its museums with intelligence, or to acquaint himself with its fossils in the field.

The most important of the natural history collections are contained in the Museum of the Polytechnicum, which is built on high ground overlooking the lake. The Polytechnicum was established in 1855, at a cost of about £100,000, and is upheld entirely by the state at an annual charge of over £18,000. The fossils are arranged in two large well-lighted rooms. From the windows there are superb views of the Alps. The peaks of the Glärnisch, Sentis, and Tödi are visible in clear weather. The fossils are arranged in the cases in stratigraphical order, but are not so much subdivided as at Brussels; whilst in the drawers which are not exhibited, except on requisition, to the public, a strictly zoological arrangement is followed. Where there is plenty of space this may be looked upon as perhaps the best method that can be adopted. The needs of the student of stratigraphical geology are met by what is virtually a full type collection, and the zoologist can study the groups which interest him in the drawers, for which permission is readily granted. An ascending zoological order is followed throughout. The rooms are lighted from both sides. Upright cases, uniform in size and construction, are placed against the walls between the windows. Each case is divided into three parts. The uppermost is of glass, without shelving, and is reserved for bulky objects. The middle is glass-fronted and shelved, and the undermost is fitted with drawers. The desk cases are arranged in series in the centre of the rooms, and are similar in plan to those adopted for the new Natural History Museum at South Kensington, but they are of less costly material and workmanship. They are uniform in design, and very conviently arranged for the display of specimens. The fossils are loose in trays. Glass tubes are used for small objects. All of the cases are provided with drawers. Flat table cases are placed at the windows, and a series of special collections for students is arranged in them. A list of one of these series may be useful.

1. Effects of organisms.	Process of fossilisation.
2. " "	Rocks of organic origin.
3. Erosion by means of organisms.	Further changes brought about by organic remains.
4. Volcanic appearances.	Volcanic bombs; lava stream, surface of.
5. Volcanic products.	

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6. Volcanic products.	Lavas and tuffs.
7. Eruptive action.	Older rocks.
8. Ancient eruptive rocks and crystalline shales (metamorphism).	
9. Rocks of mechanical origin.	

The museum is celebrated for its palæontological collections, and is of course richest in those from Swiss horizons. The collection of fossils from the Geissberg shales is the best known; and indeed the whole collection from the Aargovian jura (curator, Dr Mœsch), is amongst the largest yet brought together. There are excellent collections from the Cretaceous and Tertiary rocks (curator, Professor Mayer), and of these, those from the Miocene occupy the greatest space. Oeningen, "the richest fossil locality in Europe," is well represented, especially by its plants (curator, Professor Heer). There are also good series of Glarus fishes, Muschelkalk invertebrates, and of Liassic fossils from the classic Schambelen. The geologist or palæontologist who wishes to study the rocks and fossils of Switzerland can advantageously pursue his studies here, and if he is fresh from the reading of Professor Heer's book, he can have under his eye much of the actual material from which it was written. In addition to the palæontological department, there are departments of mineralogy (curator, Professor Kenngott), and general and alpine geology.

On the whole there is not much to find fault with as regards the arrangement of the specimens. There is some want of labelling, probably due to the necessity of economising space. The fossils are loose in trays; but the work of putting them on tablets has apparently begun. Much trouble is taken with the register numbers; where possible they are varnished over to preserve them. The floor is of unpolished pine, a pleasant exception to most of the slippery public places of the continent.

Professor Mayer took a good deal of pains to explain the arrangements of the museum, and seemed anxious to give his visitor every possible assistance.

Lausanne.—The museum at Lausanne contains a good series of Miocene plants and of fossils from the Carboniferous rocks of the Rhone Valley and the neighbourhood of Mont Blanc. These latter rocks are of special interest to the visitor from this northern part of Britain. For a long time their geological position was in doubt. Owing to the manner in which the strata are contorted and folded, they were referred to a latter geological epoch than that to which they really belong; but by a careful determination of the fossil flora it was found that the occurrence of characteristic Carboniferous plants clearly established the age

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of the formation in which they were found. These rocks, though interesting from their flora, have yielded few faunistic remains. A species of *Blatta* only has hitherto been discovered by the persevering researches of Swiss palæontologists. The paucity of animal remains in a freshwater deposit laid down apparently under similar conditions to those which prevailed when our Lower Carboniferous shales were formed, struck me as remarkable, and it seemed especially strange that there should be an entire absence of the remains of fishes, which occur so frequently in the Carboniferous rocks of our own district. Accordingly when at Salvan, which lies on the route between Chamouni and Vernayaz, I examined, in the short time at my disposal, the slates which are piled in heaps beside the quarries and thrown down in large quantities into the Rhone Valley, with the hope of finding traces of the remains of fishes upon them. I found sufficient evidence to lead me to believe that fish remains do occur in the slates. Fossils appear to be rarer at Salvan than at other Carboniferous localities in the district, and they are generally (all indeed so far as I saw) in an exceedingly bad state of preservation. I obtained two specimens of *Annularia* from the quarrymen. They exist in the form of scarcely recognisable impressions. From subsequent inquiries at the museum of Lausanne, where my questions were kindly and fully answered by Professor Renevier's very obliging assistant, I learnt that fish remains had not at that date been recognised in the Carboniferous rocks of Switzerland. The specimens that came under my observation were exceedingly fragmentary, consisting principally of small and indistinct though apparently ganoid scales, showing traces of striation such as might with some probability be referred to the *Palæoniscidæ*. I am not therefore able to speak with that certainty which a few better preserved specimens would have enabled me to do; but I am pretty confident that subsequent observers will confirm this discovery, which is one of some importance, inasmuch as it seems to point pretty distinctly to the Palæozoic age of the rocks where it was made, and thus helps to confirm the conclusions arrived at from other evidence.

Geneva has a large and well-appointed natural history museum. In the entrance is a striking mass of quartz crystals obtained at the Tiefengletschen. The fossil collections are not as a whole in so good a state as those of recent zoology. The collection "Pictet" is, however, an exception, the strong point of which is its cephalopoda. The echinoderms are also good (M. De Loriol). The entomological collection is in splendid order (curator, M. Frej Gessner), as are also the fish (curator, M. Lunel). The museum contains good series of fossils from the Perte du Rhône (Cretaceous) and also from the Swiss glacial deposits (curator, M. Favre).

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It may be useful to give a few hints on the collection of fossils from Swiss rocks. Many tourists to Switzerland would be willing to collect if they knew the localities which gave greatest promise of success. Great disappointment is usually experienced in the attempt to collect fossils in the higher Alps. Gault specimens are, however, pretty easily procurable, though in fragments, on the road from Alpnach to Pilatus. The locality is not difficult to find. Another good locality is the Iberg, which in some parts is very rich in fossils; but they are for the most part in bad preservation, as indeed is generally the case with specimens found in the Alps.

For Neocomian fossils, good localities are Haute Rive (Neuchâtel) and St Croix (Vaud). For Carboniferous, the Col de Balme, Salvan, &c.

A good locality is Brugg or Baden, and the neighbourhood is much frequented by Swiss students. They are situated in an interesting valley. There are good exposures of rocks, ranging in age from the Trias to the Miocene. Living is cheap in the villages round. The fossils are usually got from the quarries or from the vineyards after a heavy rain. Most of the Jurassic species are obtained there, and it is near to Schambelen, which does not appear to be by any means exhausted. A short itinerary follows,* starting from Brugg.

First day.—Schambelen, Mülligen, Birmenstorf, Brugg.

Second day.—Remigen, Geissberg (Kammerfels, first locality for Aargovian III.), Gausingen, Etzgen (Trias); walk along the Rhine to Schwatterloch (Muschelkalk), cross to Albbruck (Germany) ,and return by railway; or return from Schwatterloch to Wyl ,Hottwyl, Remigen, Brugg.

Third day.—Rail to Baden. Walk to Wettingen through the vineyards; rail from Wettingen to Othmarsingen (Miocene quarry); walk to Wildegg (Upper Jurassic) and Auenstein (*crenularis* shales, quarry), return to Wildegg and Brugg.

Fourth day.—Baden, Lagern (up through the vineyards near Wettingen), Schloss-stein, and return.

Fifth day.—Aarau (museum), Schönewand, Olten, Solothurn, (museum), and back.

Paris.—The museums at Paris are too well known to require much description. An entire building is devoted to palæontology in the *Jardin des plantes*; and the museum of the *École des mines* is celebrated for its extent and importance. The latter contains Deshayes' collections. In the *Jardin des plantes* a new building is in course of construction, which when completed will contain the zoological collections now lodged in a building deficient in light and otherwise unsuited for purposes of exhibition. MM. Fischer and Renault kindly gave me every

* Drawn up by Dr Haensler.

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facility for examining the collections under their charge. M. Renault drew my attention to a very interesting suite of specimens in the collection of fossil plants. It consisted of reproductions in wax of fossil fruits from natural casts. The Tertiary deposits of the Paris basin yield specimens very well suited for this process, and the result is truthful and lifelike.

Conclusion.—Of the museums visited those of Zürich, Geneva, and Paris were those from which most could be learnt that would be useful to museum officials in this country. The essentials of an effective museum from the exhibition point of view are good light and plenty of room, and next good casing and good arrangement. All of these were seldom found united in any museum visited. There was an abundance of instructive objects in all, and competent knowledge of the material accumulated. Many of the collections noted, however, are lodged in old buildings that have not been specially constructed for them. On the whole it may be safely said that the best museums of natural history established in the United Kingdom are rather in advance of than behind the majority of continental institutions of the same rank.

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X.—*Notes on the Genera of Gasteropod Mollusca from the Carboniferous Limestone Series of the Central and Western Coal-Fields of Scotland.* By JOHN YOUNG, F.G.S.

(Read 28th April 1881.)

In looking over the "Transactions" of this Society, I find no reference in any of the Carboniferous papers, specially treating on fossils, as to the genera of gasteropod mollusca that characterise the limestone strata of the Lothians and eastern coal-fields of Scotland. It has therefore occurred to me that a short paper, pointing out the genera that have been found in the central and western coal-fields of Scotland, might be of some interest to those members forming collections of Carboniferous fossils, and might also induce some of them to put upon record the species of gasteropoda that they know to have been found in the districts around Edinburgh, for the sake of comparison with those obtained from other parts of the country.

In doing this for the central and western coal-fields, I shall first point out the conditions under which the gasteropoda are chiefly met with in our beds, and afterwards indicate the genera and species known to me, so far as these have been determined.

The Carboniferous gasteropoda found in our limestone strata are all essentially of marine types; no forms belonging to this group have ever yet been met with in beds of lacustrine or estuarine origin, that alternate with the coal strata in the limestone series; nor have any terrestrial, air-breathing, univalve molluscs been met with in any of the strata that are known to have been formed over land surfaces of the Coal period, like those discovered in the Coal-measures of Nova Scotia by Dr Dawson.

Only some sixteen genera and subgenera of gasteropods have as yet been recorded from our limestone strata, but an exhaustive and critical examination of the whole group that have been found is much to be desired, as there are certain forms provisionally allocated with certain genera which on closer and more correct examination may yet be shown to be distinct, whilst there are also a number of species, in the several Scottish collections, that are either new to science, or are new to the Carboniferous strata of this country, and which still await determination at the hands of some palæontologist.

The Scottish Carboniferous univalve mollusca are as a rule considerably smaller in size than species of the same genera found in the limestone strata of England, Ireland, and other

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countries where similar strata prevail. This shows that some dwarfing influence was at work; and it has likewise been noticed amongst the other groups of the mollusca. The causes that led to this dwarfing may be difficult to explain; but probably it was due to less favourable conditions of the sea-bottom on which they lived, brought about either by temperature, depth of water, its freshness or saltness, or by the nature of the sediments that were being deposited. In connection with this point, I may here observe that the remains of gasteropoda are much rarer in the beds of purer limestone than they are in the impure limestones and calcareous shales with which they occasionally alternate. But, as sometimes happens, when the purer limestones do contain gasteropoda, as is the case at Bathgate, Carluke, Campsie, and elsewhere, the same species attain a larger size than they do in the shales. Had the collector of Scottish Carboniferous univalves, however, to depend entirely upon the species found in the richer limestones, I am afraid there would be only a very meagre list to show of either genera or species from our limestone strata, as what have been noted has been chiefly obtained from the impure argillaceous limestones and shales. This seems to show that our Scottish Carboniferous gasteropoda selected an argillaceous sea-bottom for their habitat, in preference to those tracts of the ocean's bed where only a pure calcareous sediment was being deposited. This is well illustrated by the thick bed of limestone at present worked so extensively in the quarries at Trearne, and Dockra near Beith in Ayrshire. This limestone is exceedingly rich in nearly all the groups of marine Carboniferous fossils, with the exception of the gasteropoda, which are seen to be very rare, but in other quarries of the Beith and Dalry district, where this limestone becomes more argillaceous, as at the Law and Baidland quarries, gasteropods are found more plentiful.

We have clear evidence in Scotland that many of the genera and species of gasteropods found in the Carboniferous Limestone series had a long extended life range backwards into Calciferous sandstone times, being found in the marine limestones and shales of that group in the Lothians and Fife; and probably in still lower horizons of the Calciferous strata, as in the Red Sandstone series of Arran and Dumfriesshire. Mr J. W. Kirkby, in his recent valuable and exhaustive paper "On the Zones of Marine Fossils in the Calciferous Sandstone Series of Fife" ("Quart. Journ. Geol. Soc. London," 1880), gives a list of eleven genera of gasteropods which he had discovered in that group, all of which extend upwards into the Carboniferous Limestone series, with the exception of that little univalve shell of somewhat doubtful affinity and habitat, *Littorina Scoto-burdigalensis*, Etheridge, jun., of which Mr Kirkby describes a second species under the

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name of *L. bilineata*. This shell does not appear to have been noted as occurring above the horizon of the lower division of the Burdiehouse limestone, where from its vast numbers in the stone it forms the "Buckiefake" band of the miners. That it does not belong to the true marine *Littorinidæ*, which are shore molluscs, living chiefly within tide marks, I have long been satisfied, from its mode of occurrence in the above limestone as well as in the Fife beds, and I am pleased to learn from Mr Kirkby that Mr Etheridge purposes placing it in a new genus.

In the remarks which follow on the genera found in the Carboniferous Limestone series, I shall take them in the order in which they are given in Woodward's "Manual of Recent and Fossil Shells." My information as to their distribution and mode of occurrence has been chiefly derived from the study of those found in the central and western coal-fields of Scotland, but I have likewise had opportunities of examining specimens from the Lothians and Fife, and I have no doubt but that most of the characteristic genera will be found pretty evenly distributed in the limestone strata in the east, as they are in the west, over those areas where the conditions of deposition of the sediments were somewhat similar, although, no doubt, there will often be found considerable variations as to the relative abundance of certain genera and species, even on the same geological horizons, between one district of country and another within the boundaries of our coal-fields, due to possible causes that have already been stated.

Naticopsis, M'Coy (subgenus of *Natica*), is represented by three species from the Calciferous series of Fife,* viz., *N. plicistria*, Phill.; *N. elliptica*, Phill.; and one undetermined form. In the Carboniferous Limestone series nine species are known, several of which range from the Lower to the Upper Limestone group. The genus is not abundant in any of the localities where it is found, and several of the species are very rare. The best preserved examples are those from the shales, those from the limestones are often in the form of casts. Several of the specimens found still show traces of colour markings. The commoner species are *N. plicistria*, Phill.; *N. variata*, Phill.; *N. Omaliana*, De Kon. The rarer forms are *N. canaliculatus*, M'Coy; *N. elliptica*, Phill.; *N. lirata*, Phill.; *N. elongata*, Phill.; *N. Robroystonensis*, Young and Armstrong; *N. tabulatus*, Phill. This species, which has not previously been recorded from our strata, is found in the Upper Limestone series at Glencart, Dalry, a locality that has

* All the Calciferous genera here quoted are taken from the list appended to Mr Kirkby's paper to which I have formerly referred, and the principal localities for the Carboniferous Limestone species, of the central and western coal-fields of Scotland, will be found in the "Catalogue of the Western Scottish Fossils," 1876, unless except when otherwise stated in the text.

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recently yielded several new and rare forms of Carboniferous univalves, in a wonderfully fine state of preservation.

Eulima, Risso.—This genus has not been recorded from the Calciferous series of Scotland. In the Carboniferous Limestone group it is represented by only one species, *E. Phillipsiana*, De Kon. It ranges from the Lower to the Upper Limestone strata, but is rare in all the localities, and has been chiefly found in the shales.

Niso, Risso (subgenus of *Eulima*).—This interesting subgenus has not hitherto been recorded from Carboniferous strata. I have, however, been able to determine its occurrence in the Upper Limestone strata at Glencart, Dalry, in which several examples have turned up. Externally the shell resembles *Eulima*, but is characterised by having the axis or columella perforated, a character which is beautifully seen in the Glencart specimens. The only other Palæozoic species of the genus I have found recorded is *Niso Darwini*, De Kon., from the Devonian of Australia, but our species differs from it in being smaller and more slender in its whorls. Previous to its discovery in Australia, *Niso* was not known as occurring in strata older than the Eocene. It is therefore of interest to be able to record it from other Palæozoic strata so distantly removed from that of Australia.

Loxonema, Phillips.—Mr Kirkby identifies two species of the genus from the Calciferous of Fife, viz., *L. rugifera*, Phill., and *L. scalaroidea*, Phill. In the Carboniferous Limestone series nine species have been recorded. They are chiefly found in the shale beds that alternate with the limestone, in which strata several of the species appear to be restricted both in their vertical and horizontal distribution. The most abundant species in all the beds is *L. scalaroidea*, Phill., which also presents us with one or two varieties, and ranges from the Lower to the Upper Limestone strata. The others are *L. brevis*, M'Coy; *L. clathratula*, Young and Armstrong; *L. constricta*, Mart.; *L. curvilinea*, Phill.; *L. Lefebvrei* (?), Lév.; found chiefly in the form of casts. *L. polygyra*, M'Coy; *L. rugifera*, Phill.; and *L. sulcatula*, M'Coy. The smaller species are chiefly found in the washing of the weathered shales.

Macrocheilus, Phillips.—Four species of this genus is recorded from the Calciferous series of Fife, viz., *M. imbricatus*, Sow.; *M. acutus*, Sow.; *M. fusiformis*, Sow.; *M. striatulus*, Kirkby. In the Carboniferous Limestone strata seven species are noted, and one or two others await further investigation. The genus ranges from the Lower to the Upper Limestone shales, but the greater number of the species have been found in the upper beds. The most abundant are *M. acutus*, Sow; *M. fusiformis*, Sow.; *M. imbricatus*, Sow. The rarer species are *M. Michotianus*, De

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Kon.; *M. rectilineus*, Phill.; *M. semistriatus*, Young and Armstrong; *M. tricinctus*, M'Coy. The species that attain the largest size are *M. imbricatus*, *M. Michotianus*, and *M. acutus*.

Siliquaria.—This genus, which appears not to be recorded from strata older than the Eocene Tertiary, is represented by fragments of what I take to be three specimens of the shell discovered by Dr Rankin, Carluke, in the Upper Limestone shales of that district. These specimens form portions of a spiral tubular shell having an open slit along the outer or dorsal margin; the lines of growth of the shell, which is moderately thick, runs obliquely round the shell to near the margin of the slit, where they become parallel to it, showing that the slit is not due to accidental fracture. As I can only somewhat doubtfully identify these specimens with *Siliquaria*, I have provisionally described them this last session before the Natural History Society of Glasgow as belonging to that genus (?), naming the shell *S.* (?) *carbonaria*, to denote the formation from which they were obtained.

Lacuna, Turton.—Mr Kirkby records this genus from the Calciferous strata of Fife, identifying the species, doubtfully, as the *L. antiqua* (?), M'Coy. A somewhat similar shell, with depressed spire, and wide open umbilicus, occurs somewhat rarely in the weathered limestone of the Law Quarry, Dalry, and in calcareous nodules at the base of the Lower Carboniferous limestone group at Cunningham Baidland, Dalry. I here venture to refer it doubtfully to *Lacuna* (?), and add the genus to our lists.

Turbo, Linné.—This genus does not seem to have been noted from the Calciferous series. In our Carboniferous Limestone strata two species have been recorded, these are *T. biserialis*, Phill.; and *T. spiratus*, M'Coy. They appear to be rare in all the localities, although small, strong, shelly operculæ, doubtfully referred to this genus, are not uncommon in both the Lower and Upper Limestone strata, but these operculæ may belong to some of the other genera of univalves.

Trochus, Linné.—Mr Kirkby records *T. serrilimba*, Phill., from the Calciferous strata of Fife. In the Carboniferous Limestone series the genus has been found in both the lower and upper beds, three species being noted, of which *T. biserratus*, Phill., is by far the most abundant, but is somewhat local in its distribution. The other species are *T. coniformis*, De Kon.; and *T. lepidus*, De Kon. They are chiefly confined to the shales, which have also yielded one or two other undetermined forms that are doubtfully referred to *Trochus*, but some of which may be related to *Platyschisma*, M'Coy, a genus not yet recorded from our strata.

Elenchus, Humphry (subgenus of *Trochus*).—This subgenus has not yet been noted from the Calciferous series. From our

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Carboniferous strata it was first recorded by Mr James Armstrong and myself, in our paper "On the Fossils of the Robroyston Limestone near Glasgow" ("Transactions Geological Society of Glasgow," vol. iv. p. 278), but through an overlook was not recorded amongst the list of gasteropods in the "Catalogue of Western Scottish Fossils." At least two species of *Elenchus* occur in our strata, and are found in both the Lower and Upper Limestone shales. These have been provisionally identified with M'Coy's species from the Irish Carboniferous Limestone, viz., *E. antiquus* and *E. subulatus*. The tooth on the pillar-lip in our Scottish specimens is well defined, a character which enables these shells to be readily recognised from that of *Macrocheilus*, with which they are liable to be confounded from the similarity of external form, especially if the tooth on the pillar-lip should chance to be obscured by the limestone or shale of the matrix.

Euomphalus, Sowerby.—In Mr Kirkby's list from the Calciferous strata of Fife, this genus is recorded by four species. These are *E. carbonarius*, Sow.; *E. catillus*, Martin; *E. neglectus*, M'Coy; and *E. acutus*, Sow. In the Carboniferous Limestone group eleven species have been noted, but it is just probable that some of these are only varieties of one good typical form, for on close examination it is seen that some of the so-called species run into one another so closely that it is often difficult to determine to which they belong. They range from the Lower to the Upper Limestone shales, but the most abundant form in all the beds is *E. carbonarius*, Sow. The others which are somewhat rare, and more restricted in their distribution, are *E. acutus*, Sow.; *E. calyx*, Phill.; *E. Dionysii*, Goldf.; *E. marginatus*, M'Coy; *E. pentangulatus*, Sow.; *E. pileopsideus*, Phill.; *E. pugilis*, Phill.; *E. radians*, De Kon.; *E. tabulatus*, M'Coy; *E. tuberculatus*, Flem. To this list I add another species, *E. serpula*, De Kon., from the Glencart limestone, Dalry, which is characterised by its open disconnected whorls.

Pleurotomaria, Defrance.—Of all the Carboniferous Limestone gasteropoda, this genus is represented by the greatest number of species, no less than fifteen being recorded, while there are at least five or six other forms, in the several Scottish collections, that appear to be quite distinct from any of those that are named. Mr Kirkby only notes one species from the Calciferous series of Fife, viz., *P. Yvanii*, Lév. Those from the Carboniferous Limestone group are *P. altavittata*, M'Coy; *P. Benediana*, De Kon.; *P. carinata*, Sow.; *P. conica*, Phill.; *P. contraria*, De Kon.; *P. expansa*, Phill.; *P. Frenoyana*, De Kon.; *P. Galleottiana*, De Kon.; *P. monilifera*, Phill.; *P. multicarinata*, M'Coy; *P. ovidea*, Phill.; *P. striata*, Sow.; *P. undulata*, Phill.; *P. Youngiana*, Armstrong; *P. Yvanii*, Lév. To this list I add other two named species, *P. granulata*, De Kon., Inker-

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man pits, Paisley; and *P. acuta*, Phill., Glencart, Dalry. This last is a reversed or sinistral shell, and has only as yet been met with in this locality in our strata. The above group of *Pleurotomaria* are chiefly found in the shale beds, and in one or two of the impure limestones. Many of them are rare, and confined to special horizons; but one species, *P. monilifera*, is abundant in many localities, and is found in both the lower and upper beds.

Murchisonia, D'Archiac.—Mr Kirkby finds five species of this genus in the Calciferous strata of Fife, some of the species being abundant, These are *M. elongata*, Portl.; *M. quadricarinata*, M'Coy; *M. striatula*, De Kon.; *M. angulata*, Phill.; *M. sp.-nov.* (?). Seven species are noted from the Carboniferous Limestone, some of which range from the lower to the upper beds. These are *M. angulata*, Phill.; *M. elongata*, Portl.; *M. fimbricarinata*, Young and Armstrong; *M. quadricarinata*, M'Coy; *M. striatula*, De Kon.; *M. subsulcata*, De Kon.; *M. Urei*, Flem. Besides the above, there are three or four other species from the Glencart beds that appear to be new. The distribution of the genus is very much that of *Pleurotomaria*, both genera being found together in the same beds. The *Murchisonia* most abundant are *M. striatula* and *M. Urei*, both small forms, which are probably only varieties of one species. The others are all more or less rare.

Platyceras, Conrad (subgenus of *Pileopsis*).—Four species of this subgenus are recorded from our Carboniferous Limestone series, but it has not yet been noted from the Calciferous group. The species found in our strata are *P. angustatus*, Phill.; *P. carinatus*, M'Coy; *P. neritoides*, Phill.; and *P. vetustus*, Sow. They are all rather rare shells, the last named species in the list being the most common form. It is found in both the limestone and the shales,

Dentalium, Linné.—Mr Kirkby has found two species of this genus in the Calciferous series of Fife. These are *D. priscum*, Goldf.; *D. Scoticum*, J. Young. In our Carboniferous Limestone strata five species have been recorded, viz., *D. ingens*, De Kon.; *D. inornatum*, M'Coy; *D. priscum*, Goldf.; *D. Dalryense*, J. Young; *D. Scoticum*, J. Young. These forms are met with chiefly in the shales, and although somewhat local in their distribution, several of the species are very abundant in the shales in which they are found, such as *D. inornatum*, *D. priscum*, and *D. Scoticum*. Some of these forms of *Dentalium* have sometimes been mistaken for small *Orthoceras*, but sections made through the middle of the shell in their longest direction will tell at once to which genus they belong, the *Dentalium* not being chambered like the *Orthoceras*.

Chiton, Linné, and the subgenus *Chitonellus*, Lamarck, have as yet only been recorded from our Carboniferous Limestone strata, in which they are met with chiefly in the form of

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detached plates. Of chitons proper three species have been noted. These are *C. gemmatus*, De Kon.; *C. humilis*, Kirkby; and *C. Burrowianus* (?), Kirkby. The subgenus *Chitonellus* is represented by two species, *C. Youngianus*, Kirkby; and *C. subquadratus*, Kirkby and Young. These forms are all very rare in the beds from which they have been obtained both in the Lower and Upper Limestone strata, but the recent discovery by Mr James Bennie of the Geological Survey, of a deposit of weathered limestone at the old Law Quarry, near Dalry, Ayrshire, in which the remains of *Chiton* and *Chitonellus* are comparatively abundant, and apparently of distinct species from those here named, is likely to lead us to a clearer and much fuller knowledge of these interesting organisms.*

The gasteropods representing the *Nucleobranchiata*, the highest division of this group of the mollusca, are represented by only two genera in our Carboniferous Limestone strata, viz., *Porcéllia* and *Bellerophon*.

Porcéllia, Léveillé.—This genus is represented by only one species in our strata, which is also very rare, viz., *P. armata*, De Verneuil, but has been met with in both the lower and upper beds. The genus has not yet been noted from the Calciferous series, although it has been stated to range from the Devonian to the Trias.

Bellerophon, Montfort.—Mr Kirkby records three species of this genus from the Calciferous strata of Fife. These are *B. costatus*, Sow.; *B. Urii*, Flem.; and *B. decussatus*, Flem. In the Carboniferous Limestone strata of our Scotch coal-fields the genus is well represented, no less than twelve species being recorded, viz., *B. apertus*, Sow.; *B. cornu-arietis*, Sow.; *B. decussatus*, Flem.; *B. Duchastelli*, Lév.; *B. Dumontii*, De Orb.; *B. hiulcus*, Sow.; *B. Larcomi*, Portl.; *B. Leveilleanus*, De Kon.; *B. Oldhamii*, Portl.; *B. tangentialis* (?), Phill.; *B. tenuifascia*, Sow.; *B. Urii*, Flem. Many of the species in the above list, however, are very rare, and seem to be restricted to certain horizons in the Lower and Upper Limestone series. *B. decussatus* and its varieties, along with *B. Urii*, are the common and most abundant forms in all the fossiliferous localities. *B. cornu-arietis* seems only to be known as casts in certain of the limestones where it is associated with casts of large examples of *B. Dumontii*. The most of the others are met with in the shales.

* The *Chiton* remains from the Law Quarry have recently been examined by Mr Robert Etheridge, jun., F.G.S., along with two other species from Williamwood, Cathcart, south of Glasgow. In a paper which he communicates to the Natural History Society of Glasgow, he identifies twelve species, eight of which he refers to *Chiton*, and four to *Chitonellus*. These he provisionally names as follows:—*Chiton Armstrongianus*, Ether.; *C. Loftusianus*, King; *C. Dalryensis*, Ether.; *C. solæformis*, Ether.; *C. cordatus*, Kirkby; *C. Geikiei*, Ether. Two species undetermined, *Chitonellus Benniei*, Ether.; *C. Kirkbyanus*, Ether.; *C. patelliformis*, Ether. One species undetermined.

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The foregoing is a very brief notice of all the genera of gasteropods that I know to have been obtained from our Scottish Carboniferous Limestone series up to the present. I confidently expect, however, that the list will yet be increased, both by future discoveries, as well as by a more correct determination of what has been already found. A comparison of the table of Calciferous genera with those from our Limestone series, show eleven from the former and nineteen from the latter group of strata; ten of the Calciferous genera being recurrent in the later formed beds, while nearly all of these genera are represented likewise by a greater number of species. This, however, is what might naturally be expected, when we consider how much longer the limestone strata of our coal-fields has been explored, and the much greater tract of country investigated when compared with that of the Calciferous series, in which I expect further discoveries will yet be made.

TABLE OF GENERA.

	Calciferous Series.	Carboniferous Limestone Series.
Naticopsis,	×	×
Eulima,		×
Niso,		×
Loxonema,	×	×
Macrocheilus,	×	×
Siliquaria (?),		×
Littorina,	×	
Lacuna (?),	×	×
Turbo,		×
Trochus,	×	×
Elenchus,		×
Euomphalus,	×	×
Pleurotomaria,	×	×
Murchisonia,	×	×
Platyceras,		×
Dentalium,	×	×
Chiton,		×
Chitonellus,		×
Porcéllia,		×
Bellerophon,	×	×

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XI.—*Preliminary Notice of a Clay Shell-bed between Newton and Strachur, Loch Fynne, Argyllshire.* By W. IVISON MACADAM, F.C.S., F.I.C., Lecturer on Chemistry, and Analytical Chemist, Edinburgh, *Honorary Secretary to the Society.*

(Read 28th April 1881.)

The bed to which this paper refers stretches along the east shore of Loch Fynne, and can be seen at low water mark at many points between the village of Newton and Strachur Bay. It is most largely developed at the latter point. At Tigh-na-criche the clay is fine in composition, and is employed by the people of the locality to whiten the hearthstones before the fire.

On subjecting a sample of the clay to chemical analysis, the following results were obtained.

Ferric oxide, Fe_2O_3	16·08
Aluminic oxide, Al_2O_3	22·83
Calcic oxide, CaO	2·55
Magnesic oxide, MgO	1·96
Silica, &c., SiO_2	56·58
	100·00

The mica slate of the district yields the percentage quantities given below.

Ferric oxide, Fe_2O_3	16·91
Aluminic oxide, Al_2O_3	22·12
Calcic oxide, CaO	0·65
Magnesic oxide, MgO	1·44
Silica, &c., SiO_2	58·88
	100·00

This clay deposit contains large numbers of shells, and a few of the more readily obtained have been kindly named for the author of this notice by Mr Thomas Stock, of the Natural History Department, Museum of Science and Art, Edinburgh.

PRELIMINARY LIST OF CRUSTACEA AND MOLLUSCA FROM THE CLAY-BED AT TIGH-NA-CRICHE, LOCH FYNNE.

Balanus, sp.
Ostrea, sp.
Pecten varius, Linn.
Pecten islandicus, Müll.
Astarte compressa, Mont.
Cyprina islandica, Linn.
Tellina lata, Gmel. (?)
Macoma tenuis, Da Costa.
Mya truncata, Linn.
Mya arenaria, Linn.
Littorina, sp.
Natica, sp.
Neptunea, sp.

The author is investigating the subject more fully.

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XII.—*Notice of Veins of Specular Iron Ore at Strachur, Argyllshire.* By W. Ivison Macadam, F.C.S., F.I.C., &c., Lecturer on Chemistry, and Analytical Chemist, Edinburgh, *Honorary Secretary of the Society.*

(Read 28th April 1881.)

The upper reaches of Loch Fynne were in past ages of great importance on account of the metals obtained in the district.

The very numerous bloomeries which are to be found studded over that part of Argyllshire testify to the importance of the iron industry as carried on in bygone years.

The country was especially adapted for the rude but somewhat perfect process used in the older methods for extracting iron from its ores. The steep hill sides afforded capital ground on which to erect the furnace, whilst the oak wood which grew in the immense forests that covered the whole surface of the lower ground, yielded the charcoal necessary for the smelter. So important an element was this wood, that long after the use of the native ores had been discontinued, red iron ore was shipped from Cumberland to Furnace to be worked up into the commercial article. Furnace derives its name from the iron-works which until comparatively lately were in regular work at that place.

The native ore of iron which was employed in the manufacture of this Scotch iron is a specular iron ore. It is found in the mica slate in veins, generally in extremely small quantities, and such as at the present high rate of wages renders them commercially useless. They are found in large numbers, and the grains of ore are also distributed through the surrounding rock. You thus find that the houses in the district, and which are built of this mica slate, become rapidly discoloured, ugly ferruginous blotches appearing. The veins run generally north-east and south-west. I have made several analyses of the ore and also of the surrounding rock. The specimens being (1) the ore picked as pure and free from rock as possible; (2) the ore as found in the veins; and (3 and 4) the surrounding rock mass. The results are as follows:—

	Ore picked.	Ore as in Vein.
Fe_2O_3	88·83	37·51
CaO	trace.	0·28
MgO	trace.	trace.
SO_3	0·16	0·25
SiO_2, and silicates,	10·92	61·79
	99·91	99·83

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	Mica Schist close to Veins.	Mica Schist 6 feet from Iron Veins.
Fe_2O_3	16·03	15·18
CaO	0·38	0·36
MgO	0·98	0·84
SO_3	0·12	0·09
Silicates,	82·49	83·53
	100·00	100·00

The insoluble silicates, after being fused, yielded the following results :—

Fe_2O_3	1·12	1·73
Al_2O_3	15·88	22·12
CaO	0·21	0·19
MgO	0·46	0·61
SiO_2	64·32	58·88
Soluble in acids,	18·01	16·47
	100·00	100·00

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XIII.—*Note on the Occurrence of Anthrapalæmon Etheridgii*, B. N. Peach, *in the Ironstone above the Sandstone at Craigleith Quarry, near Edinburgh.* By THOMAS STOCK, Natural History Department, Museum of Science and Art.

(Read 26th May 1881.)

In a carefully drawn up paper * by Mr R. Etheridge, jun., Pres. R.P.S.E., six species of invertebrata, belonging to six genera, are noted from this locality. Mr Etheridge, however, explains that he was precluded from dealing with all the material that had then accumulated from the marine beds in the Calciferous Sandstone Series of the district, and that therefore his list could not be made so complete as the material existing at that time warranted. Since then a good many fossils have been collected from Craigleith by myself and others, and if these and what had been gathered previously could be dealt with by a competent palæontologist, quite a long list might be published of the fauna of the shales above the sandstone at the locality. The occurrence of *Anthrapalæmon Etheridgii*, B. N. Peach, identified from a fragmentary specimen obtained at Craigleith by myself, seems deserving of a separate notice, not only because it is an important contribution to a future list, but because it appears to be the first record of the occurrence of the species in the Lower Carboniferous rocks of Fife and the Lothians. It has lately been found in considerable abundance in the Cement Stone Series of the south of Scotland, where, however, it is limited, so far as is known, to a particular horizon. Mr Peach with great kindness took the trouble to settle the identity of the specimen, and the existence of seven parallel ridges longitudinally traversing the carapace is sufficient to diagnose it. It occurred in a thin band of ironstone of fine grain, and was associated with a small bivalve, probably a species of *Anthracoptera.*

* On our present knowledge of the invertebrate fauna of the Lower Carboniferous or Calciferous Sandstone Series of the Edinburgh neighbourhood, &c., "Quart. Journ. Geol. Soc.," No. 133, February 1878.

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XIV.—*The Granite, and the Junction of the Old Red Sandstone and the Gneiss in Lower Strathnairn (Daviot).* By DAVID CAMERON, F.G.S.E., Daviot Public School, Inverness.

(Read 26th May 1881.)

The Granite of Ben Beurlaich and Maumsale.—The hills which rise to the east of the farms of Largindour, Auchbain, and Mid-Lairgs, and form the natural boundary in this part between Strathnairn and Strathdearn, are composed of one mass of beautiful gray granite, viz., Ben Beurlaich (1575) and the smaller hill of Maumsale (1250) a little to the north of Ben Beurlaich (see Map No. 84 O.S.).

The summits of the two hills form broad platforms of granite, exposed in wide patches all round their slopes for several hundred feet lower down. The granite is also to be seen *in situ* in the hollow between the two hills. On the Strathnairn side the gneiss is *in situ* along the common base of both hills, but on the Strathdearn side the granite strikes out across the valley and is seen *in situ* near the road where it was quarried at one time.

The Old Red Sandstone from Faillie to Castletown, Daltullich.—Half way between the bridges of Daviot and Faillie the Old Red Sandstone conglomerate appears on the left bank of the Nairn for about 200 yards, with the gneiss on the right bank. The junction of the Old Red and the gneiss is in the bed of the river.

Towards Faillie Bridge the Old Red appears for about 20 yards on the right bank of the Nairn at a place between two very large boulders; the one boulder (gneiss) being in the bed of the river, nearer Faillie Bridge, and the other (granite) lower down at the mouth of a small stream. At this point the Nairn enters a deep and narrow gorge, and here we see to great advantage the gneiss on the right bank of the river, and the Old Red on the left along a course of about 200 yards, as stated above. The Old Red here is a very coarse conglomerate, particularly in the bed of the river, where large boulders are fused into the mass. It possesses but little cohesion, and it has evidently been gradually crumbling away, in fact, pieces of it can be broken with the hand without the aid of a hammer. Above the left bank of the river the gneiss is to be seen going round the Old Red in a semicircle. Both ends of this semicircle touch the river, and the radius is about 100 yards. A careful observer will find the gneiss here *in situ* in at least fifteen places. Between Faillie Bridge and the corner of the

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wood (S.S.W. and N.N.E.) the gneiss is to be seen in a line at five different points, from thence to the top of Doune Daviot (N.E.) the gneiss is seen on every side and also round the crest of the Doune (900 ft.), thus to a great extent forming the rampart of this ancient hill-fort. The gneiss is visible again *in situ* about 200 yards behind the Doune. We have traced a second line of the gneiss from Faillie Bridge to this point to show that the Old Red Sandstone conglomerate at the river is *completely detached* from the Old Red of the higher moor.

We now proceed to trace the line of junction from Faillie Moor to the burn north-east of Castletown, Daltullich. The Old Red Sandstone conglomerate goes north-east along the moor behind Faillie to a certain point about 300 yards behind Doune Daviot.

The general direction the Old Red takes from the back of Doune Daviot to the burn north-east of Castletown is N.E. by E., inclining considerably both to the right and to the left of this line as we trace it along. Of course we have to look for it in the hollows and water-courses and wherever we have a chance of finding it *in situ*; so we require to notice the general direction it takes as well as the windings of the hollows and water-courses in which it is found *in situ*. The general direction the Old Red takes from the back of Faillie to the back of Doune Daviot is N.E., and from thence to the burn north-east of Castletown, N.E. by E. All the compass directions given in this paper are magnetic.

The particular directions in which we have traced the junction line are as follows:—from the back of Faillie to the back of Doune Daviot, N.E., bending slightly to the right near the crossing of the roads, from a point about 300 yards behind the Doune to another point about 200 yards behind Balvonie, N.E. from Balvonie to the site of the old sawmill near the end of Daviot Road, N.N.E. from the old sawmill to the junction or rock section below Daviot House (*Castle* on the Map), S.E. by S. from this rock section to a point about 20 yards north-west from Daltullich Farm House, N.N.E. from Daltullich Farm House to the burn beyond Castletown, E.N.E.

The Old Red is very conspicuous along the Moor of Faillie, but very little of it is to be seen *in situ* after crossing the old road from Inverness till we reach the top of the ridge at the edge of the wood. It is visible again in a great many places from the back of Doune Daviot to the back of Balvonie; from thence it can only be traced with difficulty to the old sawmill, and it is generally found by digging in the hollow. On turning south-east by south traces of it are found in a hollow within a small fir plantation. Further on the rock is covered by at least 100 feet of sand and gravel in the form of successive terraces. But as we descend the higher terrace, we find a splendid

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rock section 26 feet in perpendicular height, showing the Old Red Sandstone and the gneiss in beautiful relation. (See Map, below Daviot Castle.) Retracing our steps till we come near the Nairnside road, and looking to the north, we observe a small stream close at hand which has cut its way through the terraces down to the Nairn. We find the Old Red Sandstone *in situ* deep down in the bed of the little stream whose sandy banks rise here to a height of more than a hundred feet. A recent landslip reveals very clearly the nature of the banks. This is where the flooded stream has cut its way through the higher terrace. From the rock section already referred to the Old Red goes north-east to the river, and forms the face of the lower terrace here. About a hundred yards lower down the river it appears on the opposite side, and again at the foot of the higher terrace at Daltullich. On going along by Castletown we find the Old Red to the right in a deep hollow, the bed of an old lake which evidently surrounded a beautiful green mound, the site of an ancient castle. We go a little further north-east to see the Old Red in the stream which comes down the mountain side, and as the summer sunset often recalls poetic fancies, we think of the old song, "Dinna cross the burn," and retrace our steps.

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XV.—*On the Chemical Composition of certain Limestone Rocks from Ballimore (Argyllshire).* By W. IVISON MACADAM, F.C.S., F.I.C., Analytical Chemist and Lecturer on Chemistry, Edinburgh, *Honorary Secretary to the Society.*

(Read 26th May 1881.)

The quarry to which this paper refers is situated near the mouth of Gleann Sluan, near Ballimore, Argyllshire.

The rock has been long wrought, and there is a limekiln attached. Besides this kiln, which is of the ordinary class of such erections, there are several old and disused ones, the formation of which is peculiar, they being so formed that a continuous process is impossible, and thus the fires had to be lighted between each charge, the contents burned, and the whole cooled before removing the charge. In this way much loss of time and money was experienced. From the mounds of refuse the quarries must be very old, as most of these mounds are now clad with the luxuriant and beautiful bright green sod characteristic of such old heaps. The section shown by the quarry is somewhat extensive, being between 160 and 170 yards broad.

At the north end the schistose rock of the district is well shown, beautifully foliated, and at this point also overlies for 62 yards, and to the depth of 4 feet, the limestone. This is the oldest part of the present face, and some very fine weatherings are to be obtained.

The limestone, which is here about 16 feet thick, is of a fine blue crystalline variety, and shows 66·44 per cent. of carbonate of lime. It contains little magnesia and iron, and the percentage is made up of *silica.* It forms a useful material for building and agricultural purposes.

At the south end of this limestone a fault is observed in which the stone is much crushed and broken, and a bed of *white* rock is to be seen. This bed contains 85·16 per cent. of silica and silicates, and with 12·68 per cent. of aluminic oxide (alumina) as silicate. It has only 5·72 per cent. of calcic carbonate (carbonate of lime), and contains 5·11 per cent. of magnesic oxide (magnesia) as silicate. This white bed also appears further down, and runs through the rock for a distance of about 17 yards, tending upwards. Below this a somewhat cinder-like deposit is observable. The substance is composed of 80·64 per cent. of silica and silicates, has 7·36 per cent. of aluminic oxide (alumina), and only 0·19 per cent. of magnesic

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oxide (magnesia) as silicates. Below this again a bed of 6 feet of limestone is seen in which the iron has been changed to the oxide, the crystals of limestone being of a beautiful red colour. It is the most pure part of the stone, has 84·86 per cent. of calcic carbonate (carbonate of lime), and only 0·54 per cent. of magnesic carbonate (carbonate of magnesia), with 12·28 per cent. of silica; this bed also tends upwards.

A stratum of 61 yards of blue limestone is next seen, overlaid by a thin layer of conglomerate, having a chemical composition between that of the white rock and the blue limestone. It has 38·12 per cent. of calcic carbonate and 8·32 per cent. magnesic carbonate, with 45·58 per cent. of silica and silicates. The silicates contain 5·86 per cent. of alumina and 0·55 of magnesia.

Above this a bed of white rock is again visible, and a detached portion higher up the stratum.

Another fault 3 feet wide is now encountered. It contains no foreign substance, and is filled in by broken stone.

This fault is followed by 15 yards of blue limestone 30 feet thick, and is the face being worked at the present time, dip 5 degrees true north. At this point there is about 1½ foot of soil covering. Throughout the limestone patches of very pure calcite are to be seen.

On the north side of this bed the cutting shows a very fine slickenside on the limestone, and this is covered by a slickenside of black colour, and with the following chemical composition:—silica, &c., 69·24 per cent.; carbonate of lime, 9·36 per cent.; carbonate of magnesia, 7·32 per cent.; oxide of iron, 10·56 per cent.; alumina, 1·16 per cent.

The cutting further shows a mass of clay, with boulders of granite—red and white, schist, trap, &c., and at this point is about 3 feet thick, and exposed to a depth of 20 feet. Above the clay is a layer, 3 feet thick, of large gravel covered by soil. The quarry lies N.N.E. and S.S.W. true.

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CHEMICAL COMPOSITION OF SAMPLES OF ROCK FROM THE BALLIMORE LIMESTONE QUARRIES.

	1. Black Slickenside.	2. Limestone Slickenside.	3. Blue Limestone.	4. Calcite.	5. White Changed.	6. Cindery Limestone.	7. Red Iron Limestone.	8. Grey Changed.	9. Limestone Conglomerate.
Ferric oxide, Fe_2O_3 . . .	10·56	2·43	1·14	0·32	1·03	1·12	1·24	1·21	2·32
Aluminic oxide, Al_2O_3 . .	1·16	0·25	0·18	0·44	5·13	1·37	0·42	3·87	4·74
*Calcic oxide, CaO . . .	5·24	34·10	37·21	53·67	3·20	8·73	47·51	4·79	21.34
†Magnesic oxide, MgO . .	3·47	1·34	0·35	0·47	0·94	0·07	0·25	0·78	3·91
‡ Silica and silicates, SiO_2 .	69·24	31·04	29·52	1·84	85·16	80·66	12·28	83·64	45·58
Carbonic anhydride, CO_2 .	7·97	28·23	29·63	42·72	3·59	6·94	37·64	4·55	21·19
Sulphuric anhydride, SO_3 .	1·12	1·01	1·56	0·21	0·56	0·83	0·23	0·74	0·68
Organic matter and moisture,	1·24	1·60	0·41	0·33	0·39	0·28	0·43	0·32	0·24
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Equal to—									
*Calcic carbonate, $CaCO_3$.	9·36	60·88	66·44	95·84	5·72	15·60	84·86	8·56	38·12
†Magnesic carbonate, $MgCO_3$	7·32	2·79	0·75	1·02	2·01	0·16	0·54	1·66	8·32
‡ Containing—									
Silica, SiO_2	39·74	24·68	24·08	...	62·48	70·46	6·94	58·04	37·56
Ferric oxide, Fe_2O_3 . .	9·72	1·84	1·54	...	4·12	2·48	1·52	4·76	1·52
Aluminic oxide, Al_2O_3 .	10·34	4·12	3·72	...	12·68	7·36	3·34	15·96	5·86
Magnesic oxide, MgO .	9·12	0·21	0·11	...	5·11	0·19	0·46	4·27	0·55

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XVI.—*Valedictory Address for Session* 1880–81, by D. MILNE HOME, LL.D., *V.-P.*R.S.E., President of the Edinburgh Geological Society.

(Read 26th May 1881.)

Having been invited by our Council to close this session with an address, I am glad to have it in my power to comply, and thus in some degree make up for my too frequent absence from our meetings during the past winter.

It gives me pleasure to congratulate you on the continued prosperity of the Society, judging by our increasing membership, by the number of papers read and discussed at our meetings, and by our being able to bring out annually a print of our proceedings. Our Secretary informs me that our membership now consists of 10 honorary, 173 ordinary, 55 foreign corresponding fellows, and 21 associates,—and that we are in friendly intercourse with no less than eighty learned societies in all parts of the world, receiving from them copies of valuable memoirs and transactions, which enrich our library, and are also some proof of the estimation in which our Society is held.

The Secretary has had the kindness to furnish me with a list of the papers read at our meetings during the past winter; and I have had the privilege and pleasure of reading several of these papers. The most numerous, and, as it appears to me, the most valuable, are on palæontological subjects, of which we have had no less than four from Mr Thomas Stock, and one from my esteemed friend John Young, the Curator of the Hunterian Museum, Glasgow.

We have had two or three papers on what is sometimes called superficial geology, giving an account of the gravels, clays, sand deposits, and boulders in the counties bordering the Moray Firth and the upper part of the Firth of Forth. Both of these papers I have read, and with much interest, for they each contain a large amount of information well deserving of being recorded in our "Transactions."

You are aware that these "Transactions" now form three good sized volumes, and I hope that a fourth volume will forthwith be commenced.

In referring to the proceedings of our Society during the past year, I must mention the excursions for studying the rocks *in situ*. During last summer the first excursion was in conjunction with the Glasgow Geological Society, and was for the purpose of visiting the Carboniferous strata near Beith, so rich in fossils,

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under the joint leadership of Mr James Thomson, Mr John Young of the Hunterian Museum, and Mr Craig of Beith.

The second excursion was to the district between Linlithgow and Bo'ness, under the leadership of Mr H. M. Cadell, to see the volcanic rocks and the coal-seams of the district; and also to examine the site of the famous sculptured Roman tablet which marked the termination of the Wall of Antoninus, and occupying a position of some geological interest.

I am glad to learn that *three* excursions have been arranged for this summer, as follows:—The first to be on the 18th June, jointly with the Glasgow Society, to visit the district between Linlithgow and Bathgate, under the leadership of Mr Cadell, jun.;—the second on the 2d July, to Inchkeith, under the leadership of Mr Henderson;—the third on 18th July, to the Camps Limestone Quarries, near East Calder, under the leadership of Mr Melvin.

An invitation has been received by our Council from the Inverness Science and Field Club, of which Mr Jolly, one of our members, is President, for a joint excursion to the county of Nairn, to examine some of the localities described in a paper read before our Society during the past winter by Mr Wallace of Inverness. The Council are much gratified by the proposal, but they fear that the locality is too far off to be visited by many of our members.

Passing now from our own endeavours as a Society to contribute towards the elucidation of Scottish geology, let us look around us a little, to see what is doing in that way by others, in so far as known to the public, for we ought to welcome progress in that direction from any quarter.

1. In that view, I first call your attention to a treatise quite recently published having as its title "Among the Rocks around Glasgow," by Dugald Bell, formerly Honorary Secretary to the Glasgow Geological Society.

In his preface the author states, that his "little volume makes no pretension to containing new scientific matter, or to being anything like a full or systematic survey of the geology of the district. But it is hoped, nevertheless, that a tolerably accurate idea may be gathered from it of the geological structure of the country around Glasgow, and of the principal features of interest which the rocks of the district present."

The book contains a distinct and useful map, coloured geologically, of the various formations in a district having Glasgow as its centre, extending to Stirling, Loch Lomond, the Firth of Clyde to Cumbrae, and on the south to Lochwinnoch and East Kilbride. Over nearly the whole of the map, there are arrows representing the direction of the striæ on rocks;—all, as one might expect, persistently from the north-west.

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On the subject of boulders, there is an enumeration of the largest on the shores and hills of the estuary of the Clyde, about a dozen being specified with reference to the spots where they may be seen. Let me quote a few sentences as to the position or site of these boulders :—"What is remarkable along the eastern side of the firth, and particularly near Gourock, is the immense number of boulders, great and small, scattered on and near the shore belonging to strata which are found only on the opposite shore of the firth. The beach is literally covered with fragments of these old slate rocks, far more numerous than fragments of the sandstone over which they are strewn, and great blocks of them occur every now and then, and this not only close to the shore, but to a considerable height on the hill sides. Not a ditch can be cut, or a road made, along this part of the coast, without disclosing that the superficial covering of the country is mainly made up of fragments of these old slate and quartz rocks of the highlands. There are no such rocks here from which they could have fallen. They must have been transported from the other side of the firth, and not only so, but when we examine them, we find they are not all of one sort, or corresponding with the hills immediately opposite, but that they are of many kinds, and must have been brought from various distances, some from localities far to the north and west, around the head of Loch Goil, Loch Eck, Loch Fyne, and the neighbourhood of Inveraray. There is no resisting this conclusion to those who will attentively look at the facts" (page 152).

One other extract I give to show the author's opinion on a matter in which I hope most persons will sympathise with him. He alludes to the needless demolition of remarkable boulders. "In situations where they can do no possible harm, on a bare hill side, or on the sea-shore, or by the wayside, they might surely be allowed to remain, as mute witnesses of the great changes which in past times our country has undergone. In this view, what could be more indefensible than the destruction of that fine granite boulder, which was at one time to be seen by the roadside near the Cloch? We well remember the grief and rage of one of the members of our Society, on going down one Saturday afternoon, and finding only a few fragments of it remaining; how he confounded the ignorance and stupidity of the barbarians who had been mending the road, and by whom, although there were hundreds of other stones lying about, this remarkable one had been ruthlessly demolished and broken up."

Whilst agreeing how desirable it is that such monuments of the stupendous physical changes which our country has undergone should be preserved, when it can be done without inconvenience, I cannot help thinking, that the more interesting boulders would be generally preserved, were their true character

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as records of these changes to become better known. Mr Bell's book may contribute to this knowledge, if generally read, as I hope it will be.

2. The next publication I notice as partly referring to the geology of Scotland, is a large work by Dr James Geikie, consisting of no less than 590 pages, entitled "*Prehistoric Europe.*" In this work he does not, as in former publications, confine himself to glacial and geological phenomena. He enters on a discussion of *palæontological* discoveries, which have been made applicable to supposed glacial periods, and chiefly with the view of ascertaining what trees and plants, and what kinds of animals (including man) lived during these periods, in order thereby to deduce the climates which prevailed.

I have read through most of this large volume, and with pleasure offer my humble testimony to the immense research and great ability which it displays, embracing as it does almost every country in Europe.

As regards glacial phenomena, Dr Geikie adheres to his opinion as explained in former publications, about the existence of vast ice-sheets covering the whole of Great Britain and especially Scotland, and about boulder clay being formed under these ice-sheets, by the grinding down of rocks overridden by the ice. But in this publication I think he shows less disinclination to admit the agency of floating ice;—for in the index to the contents of the volume, he actually admits as a title or heading, "*Floating Ice, Evidence, and Traces of,*" and in the body of his work, he mentions a porphyry boulder measuring 4 feet in diameter seen by him in the carse clay of Errol, which he allows had probably been carried on floating ice from the Grampian Hills, 8 or 10 miles distant (page 397).

In this part of his work, he gives an interesting account of the buried forests in the estuaries of the Tay and Forth, showing that before the period when floating ice was carrying boulders, a warmer temperature had prevailed, allowing of trees and shrubs to grow in Scotland, similar in character to those of our own time, and which were afterwards destroyed, alike by a submergence of the land and by colder conditions of climate.

I regret very much the unseemly attack made on this publication and on its author personally, by Mr Boyd Dawkins, a well known English geologist, who last year published an interesting work on kindred subjects, entitled "Early Man in Britain."

Some offence seems to have been given to Mr Dawkins by a passage in Dr Geikie's preface, which imputed to English geologists a want of sufficient attention to the evidences of glacial and interglacial formations.

One of the proofs on which Dr Geikie founded, to show that an interglacial period of temperate conditions prevailed at an

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early period in England, was the Victoria Cave in Yorkshire, where, resting on the boulder-clay, there were gravel deposits containing, as Dr Geikie alleged, human bones; these deposits again having been followed by a boulder-clay, which implied a return of extreme cold. This statement, Mr Boyd Dawkins publicly impugned in a review of Dr Geikie's book, in *Nature* newspaper of 3d February 1881, denying that those gravel deposits in the Victoria Cave contained human bones, and alleging that they contained bones of reindeer, an animal which betokened an arctic climate too cold for human beings, but of which reindeer remains, Dr Geikie had taken no notice. There would have been no harm, if Mr Dawkins had confined his remarks to a denial of the correctness of Dr Geikie's statements, but he charged Dr Geikie with *omitting* all notice of the reindeer, the presence of which *destroyed his argument;* adding that this might be taken as a sample of the mode in which he had *dealt with the whole evidence;* dealing with it, not with the impartiality of a *judge,* but as an *advocate,* who only calls witnesses who count on his side.

In answer to these severe strictures, Dr Geikie, in the following number of the newspaper, published an indignant letter, stating that Mr Dawkins was charging him with *untruth,* and was moreover misrepresenting his views. Mr Dawkins has made no reply.

I cannot help expressing regret, that a question so purely scientific should be contaminated by such unbecoming imputations put on our countryman, even though his account of the findings in the Victoria Cave may not be correct. I must however add, that having looked into the best accounts of these findings which were within my reach, I cannot say that Dr Geikie's statements are incorrect.

3. The next publication bearing on Scotch geology to which I advert, is a paper in the "Quarterly Journal of the London Geological Society" for last November, "*On the Glaciation of the Orkney Islands,*" by Messrs Peach and Horne of the Scotch Geological Survey, the same gentlemen who had previously reported on the glaciation of the Shetlands. I see also, that in April last, at a meeting of the Edinburgh Royal Physical Society, they read a paper "*On the Glaciation of Caithness.*" This last paper has not been published at length, so far as I know. But the report of it given in the *Scotsman* newspaper of 21st April, mentioned that it promulgated "a theory that the striations in Caithness were caused by a great mass of ice acting as a glacier, draining the whole of the Moray Firth area, which being opposed by a mass of Scandinavian ice, was pushed over the land into the Atlantic."

It may be remembered that in my address to this Society at

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the close of the winter session of 1879–80, I took notice of the paper "*On the Glaciation of the Shetlands*," and in like manner I now propose adverting to the recent papers on the Orkneys and Caithness.

The views put forth in regard to the glaciation of the Shetlands are repeated, and I am afraid that I must reiterate the doubts I entertained as to the correctness of these views, doubts indeed even more strongly applicable to the Orkneys and Caithness.

1. When it is said that it was the same Scandinavian ice-sheet which glaciated the Shetlands, and also the Orkneys and Caithness, I ask how that is possible, when the direction in which this alleged ice-sheet moved on these several localities is in each case so different. The paper on the Shetlands described the ice-sheet as having advanced and impinged on these islands from the north-east, as shown by the rock striations;—whilst on the Orkneys, it is stated on similar evidence to have advanced from the south-east. Now I assert, that this huge *mer de glace*, which Messrs Peach and Horne allege to have been at least 6000 feet thick, above 200 miles wide, and coming from Scandinavia, 400 miles distant, cannot have flowed in two directions, the one at right angles to the other.

2. The next doubt I have as to the correctness of this theory is, that when the striations are looked at, as recorded in the paper, instead of there being any uniformity of direction from the south-east, the striations are most diverse and discordant. As the Orkney Islands are very little elevated above the sea, there was nothing to obstruct or impede the progress over them of this great ice-sheet, by which it is said they were "*overridden*." The striations therefore should have shown everywhere general accordance in direction. But instead of this, what is the case? On almost every island, the striations show divergences,—in one case even up to 74°, and on spots at no great distance from one another. Thus in the small island of Eda, it is stated that on the shore, about a mile to the south of the Kirk of Skail, striæ were observed on an inclined rock-face trending west and south, while on the cliff top, the direction is W. 35° W., a discordance of 55° (page 652). In Pomona "along the coast line from Island Bay to Houton Head, the trend varies W. 12° to 42° N., and in one instance to W. 32° S.," a discordance of no less than 74° (p. 653). I might give other examples.

The authors of the paper must have been puzzled to account for these variations. In the case of the Shetlands, where similar variations exist, though not to the same extent, they offered an explanation, which is admittedly inapplicable to the Orkneys. In the Shetlands they suggested the action of *local glaciers*, which they said came into existence after the Scandinavian monster ice-sheet had shrunk back to its own mountains. But the Orkney

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Islands are all, with one exception, so low that local glaciers are not suggested. It is expressly admitted, that "if we except Hoy, these scattered islands *contain no mass of elevated ground which is capable of giving rise to a local ice-sheet*" (p. 654).

The only attempt at explanation is that which was in one instance also suggested in the Shetland paper, viz., that the *mer de glace* split into two currents, and flowed in different directions, the one sliding on the top of the other. Thus, to explain a discordance of 40° in Westra Island, it is said that "the ice must have been slightly deflected, as it impinged on the eastern slopes, the *lower* portion moving in the direction of the north-eastern coast line, while the *higher* strata streamed westwards over the hill tops towards Noss Head." I venture to think that such a theory requires no special refutation.

In one passage, a suggestion is made, that "where *local causes* interfered with the general movement, slight deflections are met with" (page 652). What these *local causes* are, which could deflect this huge *mer de glace* in its onward march over these small islands, are not explained.

Then the remarkable discordance in Pomona, amounting to 74°, it is said, "probably belongs to the *later glaciation*" (page 653), What this "later glaciation" means, when there were no local glaciers, it is not easy to understand.

3. The next objection I take is, that the authors entirely ignore the observations of preceding observers who had made known facts entirely subversive of the views maintained in this paper. A similar objection I took to these gentlemen's paper on the Shetlands. It applies with still greater force to their explanations of the Orkney and Caithness glaciation. Their position is, that a great *mer de glace* moved over these districts in a direction from south-east to north-west, a direction entirely opposite to that ascertained by previous competent observers. Messrs Peach and Horne surely know that the late Robert Chambers and Mr Thomas Jamieson of Ellon, travelled over Caithness for the purpose of specially examining the rock striations, and ascertaining the direction in which the striating agent had moved. With this view, Mr Jamieson travelled along the coast of Caithness, viz., from the Ord of Caithness to Duncansby Head, a distance of from 50 to 60 miles, and from Duncansby Head to Reay, along the north coast, a distance of from 40 to 50 miles, and also over portions of the interior of the country. He published a map on which he marked at numerous places the direction of the striæ, and in the paper itself the exact bearings at about twenty different localities, showing, as Mr Jamieson states, that "the impression left upon me by all I saw was, that the movement had been *from* north-west to south-east;—for where I observed any indication of a

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stosseite, it was on the north-west side" ("Lond. Geol. Soc. Quart. Journ. for 1816," p. 268). "The presence of marine organisms and the direction of the glacial striæ, which indicate a movement of ice *from the north-west, where there is now nothing but open sea for an immense distance*, together with the absence of moraines, are all suggestive of *marine* conditions having prevailed, during the deposition of the Caithness drift" (page 269).

Mr Jamieson observes, that he "did not examine the north coast of Sutherlandshire, and cannot say how far in that direction the same characters extend" (page 271).

But this information for the Sutherland coast had been supplied by Robert Chambers, who had previously travelled along the west and north coasts of Sutherland, as far as the boundary between it and Caithness. He found on the hills near the west coast (and up to a height of 1700 feet) striæ which showed a movement *from* the north-west and west-north-west, a direction in which, as he observes, no "local or limited mass of ice could move" ("Edinburgh Philosophical Journal for 1853," p. 250). Then "passing northward to Rhiconish (still on the west coast), we find (he says) near that place striæ *coming in from the coast, from* the north-west, and passing across a high moor with no regard whatever to the inequalities of the ground (page 252). A little farther north, at Loch Laxford, a fine surface is marked with striations from the north-west, being across the valley in which it occurs. At an opening in the bold gneissic *coast, which looks out upon the Pentland Firth*, there is strong marking in a direction from north-north-west. The high desolate tract between Loch Eribol and Tongue Bay, where there is nothing that could restrain or guide the movement of the ice, exhibits striations from N. 28° W. Striæ in nearly the same direction, viz., N. 25° W., occur 4 miles to the east of Tongue. On perfectly free ground, at Armadale, the markings point almost directly from the north. When we pass on to Caithness, we find traces of striation still from points between north and north-west, which is directly transverse to a line pointing to the neighbouring hills" (page 252).

Thus from the direction of the striations observed and recorded by him on the west and north coasts of Sutherland, Mr Chambers came to exactly the same conclusion as Mr Jamieson afterwards did, from the directions of the striations on the north and east coasts of Caithness, viz., that the movement of the ice over all this part of Scotland, had been from north-west to south-east, and not, as the authors of this paper state, from south-east to north-west.

At a still earlier period, a similar opinion, as regards the glaciation of Caithness, had been given by Sir Roderick Murchison. He states in his paper on Caithness ("Proceedings of Geological

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Society of London for 1828," vol. i. p. 34) that "the highest hills in the Brora district afford, upon their sides and summits, distinct traces of a strong diluvial current, which has swept them free of covering matter, and deposited in the plain of Clyne Milltown, a mass composed of the *debris* of the denuded hills. A large portion of the turf having been recently removed, the surface of the rock is seen to be scored with parallel lines. *The direction of the markings is uniformly from N.N.W to S.S.E.*"

In corroboration of all this testimony, that in Caithness the direction of the ice movement was from north-west, I may lastly refer to a statement by Mr Peach, jun., one of the authors of this paper. In Mr Croll's book on "Climate and Time," Mr Croll refers to information communicated to him personally by Mr Peach, jun., viz., that "near the Ord of Caithness and on to Berridale (*i.e.*, on the east coast) *the striæ pass off the land and out to sea*; but near Dunbeath, 6 miles north-east of Berridale, they begin to creep up out of the sea on to the land" (p. 453).

*With such testimony, it is impossible to doubt that the rock striations of Sutherland and Caithness were due to ice movement from the north-west, and if this was the case in these regions, it would require very strong evidence indeed to show, that the rock striations in the Orkney Islands, so near Caithness, could be due to ice agency moving in exactly an opposite direction.

At all events, it might surely have been expected that the authors of these papers, which maintained this last view, would have noticed, in order to answer if they could, the facts and conclusions adduced by eminent geologists, which if true, entirely demolish the theory of the Scandinavian ice-sheet.

4. My next doubt in regard to the paper, is suggested by the way in which *boulders* are accounted for. Messrs Peach and Horne state "that boulders do not occur very plentifully in Orkney; but we felt convinced, from an examination of those we met with, that they must have been mainly distributed during the primary glaciation ('Lond. Geol. Soc. Quart. Journ. for 1880,' p. 659). In Westray, blocks of *granite* and *quartzite* are found on the slopes of Cloat Hill, and rounded stones and boulders of *Red Sandstone* from Eda, occur in the southern district, as well as along the western shores."

The alleged transport of these Red Sandstone boulders from Eda to Westray, Messrs Peach and Horne say, "can be

* On revisal of this address, it occurs to me to add, that the existence of a great oceanic current in the North Atlantic from the north-west, during the Scotch boulder period, is further proved by the direction of the rock striations in the *Faroe Isles* and in *Iceland* ("Ed. R. Soc. Trans.," vol. xxv. p. 667). These islands as well as the British Islands were then submerged.

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accounted for by supposing, that the rocky slopes facing Eda Sound were exposed to the full sweep of the (Scandinavian) *mer de glace*" (p. 655), which "must have overtopped the hills in its north-westward march."

But I have a difficulty in understanding how any *mer de glace*, especially if it was of the enormous dimensions ascribed to it, could, whilst impinging on and passing over Eda's rocky slopes, pick up blocks and carry them to another island and there drop them. If fragments of rock were pushed off Eda, is it not more likely that when so pushed off, they would fall simply into the sea between Eda and Westray, rather than be carried across and over the sea to Westray?

Whilst this is the explanation offered by Messrs Peach and Horne of the *sandstone* boulders in Westray, what explanation do they offer of the "blocks of *granite* and *quartzite*" which are also found there? It is not alleged that *these* rocks occur *in situ* in Eda or in any other island, in the march of the *mer de glace* towards Westray.

The only island in which granite or other crystalline rocks occur, is in the south-west corner of the group, viz., in *Pomona*, near Stromness, and if these granite and quartzite blocks came from that quarter to Westray, it must have been by some transporting agent, which moved *from the south-south-west*, a direction quite discordant with the supposed movement of the *mer de glace*.

A similar remark applies to the great *Saville boulder* on Sanda Island. The late Dr Patrick Neill examined this boulder, and having also examined the rocks of Stromness, expressed an opinion that it was "a block of gneiss," "similar in quality" to these Stromness rocks. He therefore concluded, that "it somehow must have passed over 15 miles of what at present is land, and 19 miles of what is sea" ("Second Report of Edinburgh Royal Society Boulder Committee," p. 168). The direction of Stromness from the boulder is west-south-west, and in that line the sea has a depth of from 10 to 20 fathoms. If the boulder came from Stromness, it certainly could not have been transported by the Scandinavian ice sheet.

The authors of the paper state, that the only Scotch rock known to Professor Heddle, resembling the *Saville boulder*, "is to be found in Sutherlandshire." In that case it must have travelled in a direction across even a wider expanse and greater depth of sea, than that suggested by Dr Neill, and in much the same direction, viz., from west-south-west, a direction utterly at variance with a march from Scandinavia.

Messrs Peach and Horne conclude this part of their paper on Orkney glaciation, with the strange remark, that some of "the boulders resemble the thin limestone bands in the Cement Stone

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series of central Scotland, and they add that the nearest locality to Orkney, where these rocks occur *in situ*, is *in the county of Fife!*" (p. 661). Alas for the Scandinavian ice-sheet theory, if this surmise be well founded.

5. Before concluding what I have to say regarding these papers on Orkney and Caithness, I must allude to the marine shells, most of them Arctic, which occur so plentifully in the boulder-clay of both districts. To account for these organisms, and for the crushed state in which most of them are, the authors adopt the theory originally suggested by Dr James Geikie in his "Great Ice Age." They say that "the Scotch ice-sheet as it crept outwards along the bed of the Moray Firth towards the North Sea, must have *pushed along the marine shells and silt which it encountered on the sea floor.* These would be commingled with the *moraine profonde* which had gathered underneath the ice-sheet, and the shells would ultimately be smoothed and striated precisely like the stones in the bottom moraine."

If this theory be correct, it is not to be wondered at that the alleged Moray Firth glacier, pressing over the sea-bottom on its way to Caithness and Orkney, should have so crushed all the shells as to leave none entire. But it is right to observe that both Mr Peach, sen., and Mr Jamieson do not subscribe to this alleged complete destruction of the shells. They found shells in an *entire* and unbroken condition, though not plentifully. Mr Jamieson, referring to one species of shell, the *Tellina calcaren*, which was scratched on its surface, observes that "this is rather a delicate fragile shell; and the fact of its being so marked, and yet not crushed to powder, shows how gently, in some cases, the action must have been that imprinted these markings" ("Lond. Geol. Soc. Quart. Journ. for 1866," p. 269).

Now I am not inclined to dispute, that one way of accounting for the generally crushed condition of the shells, perhaps indeed the only way, is to suppose that the sea-bottom when inhabited by these living organisms was invaded by ice. But this ice need not necessarily have been land ice. In the Arctic regions, as Dr Sutherland, a surgeon in one of the Arctic expeditions testifies, the action of icebergs on the sea-bottom there, is to tear up whole *rafts of submarine forests of sea-weed*, and when the sea bottom is dredged, little else than *broken shells* are brought up ("Lond. Geol. Soc. Journ.," vol. ix. p. 306).

With reference to this theory of floating ice, I think that no little support is obtained for it by a remark which Messrs Peach and Horne repeatedly make in their paper, that whatever was the agent which striated the rocks and transported the boulders, "we are forced to conclude, that the ice movement must have been altogether *independent of the islands*" (p. 655). In another passage they remark, that "the evidence adduced regarding the

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ice movement proves beyond all doubt that the islands have been glaciated, in one determinate direction, *independently of their physical features*" (p. 654).

In respect of this conclusion, a presumption is of course meant to be suggested in favour of a *mer de glace* from Scandinavia. But the same conclusion favours equally the theory of *floating ice.* If it had been the case that the rock striations and the transport of boulders had all been "in one determinate direction," or with small divergence from it, as Messrs Peach and Horne aver, something might have been said in favour of a Scandinavian ice-sheet. But the reverse appears to be the case, for neither the rock striations nor the transport of boulders are in any one determinate direction. The directions, as I have shown, are most divergent and discordant; and such as favour the idea of floating ice brought by an Arctic current from the north-west, and when entangled among the islands diverging from its course by the action of tides and winds.

By means of floating ice, it is possible to understand how fragments of rock could be transferred from one island to another, far more naturally than by means of a great ice-sheet which invaded and swept over the whole group of islands.

I have gone thus fully into a discussion of this Scandinavian *mer de glace* theory, because of the persistent advocacy of it by so many members of our Scotch Government Geological Survey, and because I find, from the papers read in our Society during the past winter, that some of our own members are assuming that theory to have been established. I regret to differ from high official authorities, but as their object can only be the advancement of science and the discovery of truth, I am sure they will not be offended at its being shown, that the question they have started, is one with two sides, and that something may be said in opposition to the theory they advocate.

In concluding my address, I beg to thank you for the patience with which you have listened to it, and to express my cordial wishes for the continued prosperity of the Society, and my hope that during the next summer and autumn, members will have many opportunities of gathering up useful materials, which will supply papers for our meetings next winter.

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XVII.—*Joint Excursion of the Edinburgh and Glasgow Geological Societies over the Bathgate Hills, on Saturday 18th June* 1881. Mr HENRY M. CADELL, *Leader.*

About thirty members of the Edinburgh and Glasgow Geological Societies met at Bathgate on Saturday 18th June, and proceeded on a joint excursion to examine the district to the north of that town. The party included Messrs Robertson, Murdoch, Bell, Nairn, Dairon, and Mason, of the Glasgow Society; and Messrs Cadell, Richardson, Lapworth, Henderson, Hunter, M'Lachlan, Sprague, and W. Ivison Macadam (the Honorary Secretary), of the Edinburgh Society. After visiting the Calciferous sandstones, limestones, and volcanic rocks exposed in the old quarries at Kirkton, the party, under the leadership of Mr H. M. Cadell, proceeded northward along the trappean bank of the Bathgate hills, past Petershill to Silvermine, where the vein of galena worked in the time of James VI. was examined. Mr Cadell then sketched the history of volcanic action in central Scotland during the Carboniferous period. He said that the huge volcanoes which poured forth the immense sheets of porphyritic lavas and tuffs which now formed the ranges of the Pentlands, Ochils, and Sidlaws, became extinct ere the close of the Lower Old Red Sandstone period, and it was not till the beginning of the following or Carboniferous period that a renewed outburst of the volcanic fires took place. The Garlton Hills, the lower part of Arthur's Seat, and several of the Fife hills were thrown out in the east, while the volcanoes of the west poured out a series of traps which occupy the position of most of the eastern Calciferous Sandstone rocks. Towards the close of the Calciferous Sandstone period, volcanic activity decayed in the east and west, but continued in operation in Fife and Linlithgowshire during the following or Carboniferous Limestone period. The Bathgate hills consisted of an almost continuous series of basaltic lava beds, whose total thickness was about 2000 feet. The base of the series reached down below the Lower Marine or Hurlet limestone, and its highest bed was found above the Dykneuk or Calmy limestone to the west of Linlithgow. The high ground of Bonnytoun Hill, between Linlithgow and the firth, consisted of basalt sheets of the same age as those of the Bathgate hills, which had probably been ejected from a separate "neck" to the north-west of Linlithgow. These traps thin out towards the Firth of Forth, and were met with in the Bo'ness pits regularly interbedded with the coal-seams worked there. There was no indication of volcanic activity during the remainder of the Carboniferous

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period; the igneous rocks which occur among the Millstone Grit and Coal-measure strata were all intrusive, having been chiefly injected during the vastly newer Miocene period. The excursionists then visited Hillhouse Quarry, and saw the range of basaltic columns overlying the limestone there. Proceeding to Linlithgow, the party had tea at the Star and Garter Hotel, after which Mr Robertson, vice-president of the Glasgow Society, proposed the health of Mr Cadell, and Professor Lapworth proposed "The Glasgow Geological Society," to which Mr Murdoch (secretary) replied. Several other toasts were proposed, including those of Professor Charles Lapworth, F.G.S.; and Mr Ivison Macadam, F.C.S. Mr Dugald Bell then proposed the Edinburgh Geological Society, to which Mr Ralph Richardson, F.R.S.E., replied.

XVIII.—*Excursion to the Island of Inchkeith.*

2d July 1881.

The party, numbering about thirty, left Leith in the tug "Fiery Cross" for Inchkeith. The tide was at its lowest, and this enabled the party, who were led by Mr John Henderson, to survey all the strata on the shore under high-water mark. Around the northern end and a portion of the easterly side of the island, the beds are as well displayed as if pictured and sectioned on a geological map. Some new roads made in connection with the fortifications cut the strata diagonally, exposing fine sections by which the observations around the coast can be checked. Five-sixths or more of the island are great sheets of igneous rocks, between which are thinner bands of sedimentary deposits, including shales, two thin seams of coal, some highly calcareous shales, and bands of limestone. Many of the shales contain large numbers of fossil ostracodes and minute phyllopods, amongst which an *Estheria* (?) is abundant. A scale of *Megalichthys* was obtained, the first, it was understood found on the island. A prehistoric kitchen-midden was crossed on one of the new roads. When the rocks had been surveyed *in situ*, Mr Henderson gave an outline sketch of the leading divisions of the Carboniferous formation as developed in the counties bordering both sides of the Forth. Going somewhat into detail on the rocks comprising Inchkeith, he explained the character of the several strata, and said their geological horizon was near the top of the Calciferous Sandstone series. Observations had been directed to the junctions of the igneous sheets with the sedimentary beds, with the view of determining whether the traps were intrusive. Mr Henderson decided that most if not all of them were of this character.

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XIX.—*Excursion to Camps Limestone Quarries.*

MR MELVIN, *Leader.*

16*th July* 1881.

About twenty members of the Society left Edinburgh at noon on Saturday 16th July, and visited the interesting series of excavations in the Burdiehouse estuarine limestone at Camps, under the leadership of Mr Melvin of Bonnington. The western basin was first visited, and a beautifully glaciated rock surface was seen at one place where the "tirring" had been recently removed. The party then moved eastwards to the series of excavations at Raw Camps, noticing several interesting intrusive dolerite dykes on the way. After a good deal of hammering, numerous specimens, both of the animal and vegetable remains which have rendered this deposit famous, were obtained, including the characteristic fern *Sphenopteris affinis*, *lepidophloios*, scales of various ganoids, &c., while one member of the party was fortunate enough to discover a large bone or plate of a *Rhizodus*.

A portion of the thin bed at the base of the limestone locally known as the "buckie fake," from the abundance of shells of *Litorina scoto-burdigalensis* which it contains, was seen in the "stoop and room" part of the quarries, after which the excursionists disbanded their forces for the season.

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APPENDIX.

PAPERS READ BEFORE THE EDINBURGH GEOLOGICAL SOCIETY DURING SESSION 1880–81.

4th November 1880 (46th Anniversary Meeting).—1. Inaugural Address. By Ralph Richardson, W.S., F.R.S.E., *Vice-President nominate.*—2. Reports by the Secretary and Treasurer.

18th November 1880.—1. Notice of the Surface Geology of the Estuary of the Forth round Borrowstounness (Part I.). By Henry Moubray Cadell.—2. On the Occurrence of *Sphœrerochus mirus* (?) in the Ludlow Rocks of the Dudley District. By C. Beale, C.E. Communicated by Thomas Stock.—3. Note on the Occurrence of *Dithyrocaris* (?) at Craigleith. By Thomas Stock, *Museum of Science and Art.*

16th December 1880.—1. Notice of the Surface Geoglogy of the Estuary of the Forth round Borrowstounness. (Part II.) By Henry Moubray Cadell, Grange, Bo'ness.—2. Notice of a Bore Section at Abbeyhill, and its relation to the Rocks of the Calton Hill. By John Henderson.—3. On the Discovery of a nearly entire Specimen of *Rhizodus* in the Wardie Shales. By Thomas Stock, *Natural History Department, Museum of Science and Art.*

6th January 1881.—1. Recent Geological Changes on the Moray Firth. By Thomas D. Wallace, F.S.A. Scot., *High School, Inverness.*—2. The Recent Formations and Glacial Phenomena of Strathnairn. By James Fraser, C.E., *Inverness.*

20th January 1881.—Meeting adjourned.

3rd February 1881.—The Geology of Loch Skene. By Ralph Richardson, W.S., F.R.S.E., *Vice-President.*

17th February 1881.—1. A Visit to the Extinct Volcanoes of Auvergne. (Illustrated by Minerals, Diagrams, and Photographs.) By Dr W. T. Black.—2. A Critical Review of the Origin of the Gravels of Somme Valley as represented in Dr Southall's "Epoch of the Mammoth." By Frederick Smith.—3. Notes on Maulmain and Neighbourhood. By Dr Romanis. Communicated by the *Honorary Secretary.*

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17*th March* 1881.—1. Notes of Visits paid to a few Natural History Collections in the course of a Tour on the Continent in 1880. By Thomas Stock, *Natural History Department, Museum of Science and Art.*—2. Some New and Old Illustrations of the Surface Geology of the Northern Side of Edinburgh. By Andrew Taylor, F.C.S., *Associate.*—3. Notes on the Geology of the Caledonian Railway from Carstairs to Beattock, and of Moffat and Loch Skene, taken in 1862. By D. Milne-Home, LL.D., &c., *President.*

28*th April* 1881.—1. Notes on the Genera of Gasteropod Mollusca, from the Carboniferous Limestone series of the Central and Western Coal-fields of Scotland. By John Young, F.G.S., &c. Communicated by the *Honorary Secretary.*—2. Notes on Carboniferous *Ichthyopsida*—(1) On *Wardichthys.* By Thomas Stock, *Natural History Department, Museum of Science and Art.*—3. Notice of Clay-Shell Bed at Tigh-na-criche, Strachur. By W. Ivison Macadam, F.C.S., F.I.C., *Honorary Secretary.*—4. Notice of Veins of Specular Iron Ore at Tigh-na-criche. By W. Ivison Macadam, F.C.S., F.I.C.

26*th May* 1881.—1. On Mounds known as Barnhill and Auldton Motes, near Moffat, Dumfriesshire. By Ralph Richardson, W.S., F.R.S.E., *Vice-President.*—2. Note on *Anthrapalœmon Etheridgii* (B. N. Peach). By Thomas Stock.—3. Notes on Carboniferous *Ichthyopsida*, No. 2. By Thomas Stock, *Natural History Department, Museum of Science and Art.*—4. The Granite, and the Junction of the Old Red Sandstone and the Gneiss in Lower Strathnairn (Daviot). By David Cameron, *Teacher, Daviot, Inverness.*—5. On the Chemical Composition of certain Limestone Rocks at Ballimore, Argyllshire. By W. Ivison Macadam, F.C.S., F.I.C., *Honorary Secretary.*—6. Valedictory Address. By the *President*, D. Milne-Home, LL.D., *V.-P.*R.S.E., &c.

SUMMER EXCURSIONS OF THE SOCIETY.

1881.

1. 18th June (with the Geological Society of Glasgow). Bathgate Hills from Bathgate to Linlithgow. *Leader*, Henry Moubray Cadell.
2. 2d July. Island of Inchkeith. *Leader*, John Henderson.
3. 16th July. Camps Limestone Quarries. *Leader*, James Melvin, Bonnington, Ratho.

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TRANSACTIONS

OF THE

EDINBURGH GEOLOGICAL SOCIETY.

SESSION 1881-82.

I.—*Inaugural Address, Session* 1881-1882. By DAVID MILNE-HOME, Esq. of Milne-Graden, LL.D., *V.P.*R.S.L., &c., *President of the Society.*

(Read at the Anniversary Meeting, November 17th, 1881.)

FELLOWS of the Edinburgh Geological Society,—I am glad of the opportunity of coming among you once more, at the commencement of a Winter Session.

Since the termination of the last session in May, there have been several meetings of a special and useful character which deserve notice.

Opportunities for the examination of strata in their natural positions are always advantageous; for no black boards, books, or even diagrams, however faithful, can convey to the mind, what can be obtained by inspection and study at hill sides, or on river banks.

I see from our lately published Transactions, that there were three excursions to different districts of the country. The thanks of the Society are due to those members who were at the trouble to select places of interest to which access could be conveniently obtained; and thanks also are due to those members who, being previously well acquainted with the localities, were leaders of the excursionists, to draw attention to the objects for which these localities were visited.

Having referred to the Number of our recently published Transactions, I stop for a moment to congratulate the Society on our having commenced a fourth volume. The usefulness, prestige, and success of a society are much enhanced by the publication

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of its proceedings; as persons are more induced to join and work for societies, when there is a prospect of their researches being recorded and made public through such a medium.

Another meeting took place at Elgin in August, to which the members of our Society had been courteously invited. It was a meeting of the Inverness Scientific and Field Club, of which the president (and I believe the founder) is William Jolly, Esq., of Inverness, one of our own members.

The meeting was attended, besides others of our members, by Mr Ralph Richardson, who was so kind as to write to me from the place of meeting, regarding an important geological discovery, of sea shells of an arctic type, in boulder clay; and which led to a visit being made to an adjoining locality for inspecting the discovery.

This discovery of sea shells, in one of our northern counties, I consider to be of much interest, and I am glad to learn from our Secretary, that a paper by the discoverer has been forwarded to be read at one of our meetings. The importance of the "find" arises from the following considerations:—1*st*, It forms an additional link in the chain of evidence, showing, that at a comparatively recent period, geologically, the whole of Great Britain, and probably of north-western Europe, has been under the sea. In Lanarkshire, sea shells have been found in boulder clay at 526 feet above the sea. They have been found also in clay beds in Caithness, the Lewes, and the Orkney Islands, as well as in Aberdeenshire, Dumbartonshire, Ayrshire, and Wigtonshire. The height of 500 feet may not be the full measure of submergence; because when the different species of shells come to be examined, it is found that some of them generally live where the sea has a great depth. This has been ascertained, for example, to be the case with sea shells found in boulder clay or till, in Fife, Lanarkshire, and Arran. In England, sea shells occur in several localities at from 1200 to 1300 feet, and in Ireland at about the same height. But at even greater heights, we have other traces of the sea, in the extensive beds of sand and gravel found in the Highland hills up to the height of at least 2500 feet, and these beds imply, of course, a sea of still greater depth. 2*d*, Many of the shells in these clay beds, in England, Ireland, and Scotland, are of an *arctic* type; the proportion of that type being more numerous in Scotland—because geographically situated in a colder latitude; from which fact it follows, that the sea at that period very probably had ice floating in it. 3*d*, The occurrence of sea shells in these clay beds, makes it far more likely that these beds were formed at the bottom of the sea, rather than on the surface of the land under

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glaciers. As the origin and formation of boulder clay has long been a matter of difficulty and of keen controversy among geologists, it will be seen that this discovery, by Mr Fraser of Inverness, of sea shells in boulder clay at Nairn, is of much importance, and will excite general interest when his paper is read and published.

Being desirous of knowing more of the nature and objects of the society which had sent to us a courteous invitation to its meeting at Elgin, I wrote to Mr Richardson for some notice of its constitution and objects, and received from him a letter explaining that in the northern counties there are several field clubs devoted to subjects of natural history and also to archæology. These clubs are intended, by the personal enquiries and researches of its members, to discover new objects of interest—to receive notices of these, and once a year to hold joint meetings at or near some place where these objects may be examined, and opinions obtained on any questions of interest arising.

It was to a joint meeting of this kind that our Society was courteously invited to send representatives.

I am further informed that there will be a similar invitation next year.

It would appear, therefore, that this was a meeting of several societies—all more or less calculated to develop objects of physical interest in the northern counties. As it is likely to meet every year in one or other of the towns in that quarter, it may be considered as a miniature British Association for the promotion of science and natural history in the north of Scotland.

The original British Association has, after fifty years of great activity and usefulness, grown to such magnitude, in respect of membership, and it embraces now so many subjects for discussion, as to become somewhat difficult of management. I suppose it is because of this circumstance that, during the recent meetings of the Association at York, there was a proposal to devise some method of lessening the heavy duty falling on the officials of the Association, by encouraging local associations with congenial objects. In that view, the gathering of different local societies at Elgin, to which I have referred, and if held annually at some other town in the north, may well obtain encouragement from the old British Association.

II. I regretted very much my inability to go to York, but I read with interest many of the reports and discussions in the different sections. In the geological section, the report by the Boulder Committee of the Association especially interested me, as I saw that many of the facts and suggestions in the report were similar to those contained in the report of the committee appointed by the Edinburgh Royal Society.

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Let me state a few of the facts mentioned in the British Association Report. I quote from *Nature* newspaper of 15th September 1881 :—

"Particulars were given respecting granite boulders found, while excavating for the new dock at Maryport, Cumberland. These vary in size from pebbles to a ton in weight, and are rounded. The nearest granite rocks occur in the Kirkcudbrightshire hills, on the other side of the Solway, 15 or 20 miles distant."

"A boulder of *Shap* granite found near Filey (on the east coast of Yorkshire) has been removed to the University Museum, Oxford. It rested on oolitic strata 150 feet above the sea. The nearest place where granite rock of the same character is found is 108 miles distant, bearing west north-west from Filey."

"A detailed description was given of the great erratic, called the 'Holy Stone,' at Humberstone, Leicestershire. Its weight is about 21 tons. It rests on a denuded surface of the Rhoetic formation. The height from which it travelled, is about 400 feet above the sea, and is situated six miles north-west. The height at which the block rests, is about 260 feet above the sea; and there is a river valley between these two points, running at right angles to the line of transit of the block, which (valley) is only 110 feet above the sea."

"Various groups of boulders in Leicestershire were also described, some containing millstone grit blocks, derived from Derbyshire, which must have travelled about 35 miles."

"A catalogue of 191 blocks in the parish of Ashwell, Hertfordshire, was given, none being local, but derived generally from the oolites of the Midlands, and from the carboniferous of more northern districts."

The Report concluded with an appeal to local observers to give assistance in cataloguing the rapidly disappearing erratic blocks of the country.

With regard to the granite boulders from the Kirkcudbrightshire hills, referred to in this Report as found at Maryport, in Cumberland, I may mention that the late Professor Harkness found granite boulders even so far south-east as Cumberland, viz., beyond Penrith, in the Valley of the Eden, and which he recognised as *Criffel Granite* ("London Journ. of Geol. Soc. for 1870," p. 522).

With reference to the *Shap* granite boulder, named in this Report, as having been removed to the Oxford University museum for preservation, I may add that several other boulders of the same interesting character occur along the east of Yorkshire. Of these blocks, an account had been given in previous years' reports. A popular interest has now been excited re-

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garding these; and I am glad to say most of them have been preserved in the gardens and policies of adjoining proprietors.

It is hardly necessary for me to mention to those who have looked into the Boulder Reports of the Scotch Committee, that the facts regarding boulders in Scotland are, in many important respects, in entire accordance with those in the English report.

Mostly in Scotland, as in England, the *line* of transport has been from north-westerly points. The distances travelled have been in many cases above 50, in some cases 100, miles; as, for example, the mica slate boulders in the Pentlands and in Berwickshire. Then the *transport* has been in many cases in Scotland, as in England, *across deep valleys and arms of the sea.*

Having mentioned the general line of transport for boulders and drift in *England*, let me just refer briefly to what it is in *Ireland.*

Mr Jukes, in his "Manual of Irish Geology" (1862), observes that the Granite of Galway Bay is easily recognizable, inasmuch as it contains hornblende instead of mica, and has large crystals of pinkish felspar. "Blocks of it may be found scattered all over the country to the south of the Bay, through Clare and Limerick, and adjacent counties, as far south as Mallow, in the County Cork, a distance of about 100 miles" (Jukes, p. 678).

So also Sir Richard Griffith reported to the British Association, that "large erratic blocks are found resting on the surface throughout the entire district from Galway Bay in an eastern and southern direction, passing over the summits of the Slieve Bloom Mountains, and extending through the King's and Queen's Counties" (Br. Asso. Reports, 1871, p. 9).

The recent publications by Mr Hull, the Director-General of the Irish Survey, and his able assistant, Mr Kinahan, fully confirm these statements as to the general direction of boulders and drift in Ireland having been from the north-west.

The direction of transport thus agrees in each of the three divisions of the United Kingdom. But there is more than this; for chalk flints have been found along the west coast of England (as in Wales and Cheshire), and in the S.W. of Scotland, which probably came across the Irish Channel, from the north-east of Ireland, where chalk strata exist *in situ.*

In regard to the nature of the transporting agent, the English Boulder Committee, though appointed to report on the "origin" of the boulders, have very properly abstained from more than an occasional remark, when the facts plainly suggested it. In some cases, local glaciers have been pointed out as a *vera causa.* In

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other cases, and especially in regard to boulders perched on the summits or ridges of hills, floating ice has been named as indispensable (see Report VII. page 3).

The Scotch Boulder Reports contain occasional suggestions to the same effect. Indeed, when due regard is had to the one fact, that over the three parts of the United Kingdom, the general direction of transport is the same, viz., from north-westerly points, it must almost certainly have been one and the same agent, to produce that effect over so large an area of the earth's surface; and it is difficult to conceive any agent of such extensive operation, except sea covering the land, and with currents in it flowing from the north-west bearing masses of ice.

III. The next, and indeed the only other matter of general interest, to which I invite the Society's attention to-night, is the Geological Survey of the United Kingdom.

I need not point out the national importance of such a survey in a country whose manufacturing enterprise and employment of the great majority of the population, depend much on mineral products. This country would be poor indeed, in respect not only of internal wealth and comfort, but of influence in the world, were it not for our fields of coal, ironstone, shales, and other strata. I believe one of the reasons why Ireland is so helpless a member of the national family, is the want within her bounds of these useful products.

The Geological Survey has now been in progress for 20 or 30 years. Professor Ramsay, the Director-General of the Survey for the whole kingdom, has, at my request, been so obliging as to send to me notes of what is being done to carry on the survey in England, Ireland, and Scotland respectively, and I will now state what these show:—

(1) *England*, for the purposes of the survey, was divided into 110 squares, each square containing about 530 square miles.

All these squares have now been surveyed, except 8 or 9, two of these being in the middle of the East Coast, and the rest in the extreme north—viz., Northumberland and Cumberland.

During the year 1880, about 1600 square miles were surveyed. During the previous year, the amount surveyed was 1726 square miles. If the survey goes on at the same rate, the field work of the Survey for England and Wales, should be completed in less than three years.

I cannot very well make out from the returns the total number of *Maps* and *Memoirs* which have been published, as the returns sent describe only the work of each of the last three years. But I gather from an index map, that the number of Memoirs explanatory of the Maps is at least 33. During the present year, 1881, 2 Memoirs have already been published (of

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which I produce copies), and 2 were published in the previous year.

(2) *Ireland.*—For the purposes of the survey, Ireland was divided into 205 squares, each square containing 216 square miles.

The whole of Ireland has been surveyed, except about 25 squares, in the extreme north of Ireland.

The amount of fresh ground surveyed in the year 1880 was 492 square miles, with an addition of 710 square miles of old ground re-examined. In the previous year, there had been 560 square miles of fresh ground surveyed, with an addition of 1394 square miles of old ground re-examined; and in 1879 there was of new ground surveyed 691 square miles, with 209 square miles of old ground re-examined. The average of these three years of new surveys is 580 square miles; so that, if the work goes on at the same speed as heretofore, the whole survey will be completed in 9 years.

I learn that altogether 168 Maps, geologically coloured, have been published, and 85 Memoirs descriptive of the strata mapped in the sheets.

During the present year, two Memoirs have been published. One of these I have brought with me, and lay on your table.

(3) *Scotland.*—For the purpose of the survey, Scotland was mapped out into 120 squares, each square containing about 250 square miles.

Of these 120 squares, I do not learn that more than 36 have yet been surveyed.

Maps of 7 squares, on the 1-inch scale, have been published, and parts of 14 others.

There have, however, been maps on the 6-inch scale published, applicable to 9 coal fields.

I cannot make out that any Memoirs have been published during the last two years. The two last which were published are now on the table.

The number of square miles surveyed in Scotland in each of the past three years, was on an average 542 square miles. There are still 84 squares to be surveyed; but as 6 or 8 of these are chiefly sea, 75 squares of field work may be assumed to be still required to be done, containing 18,750 square miles. At the average rate of the last three years, it will take 35 years before the survey can be completed.

With regard to the value of the information furnished by the maps and memoirs of the General Survey, it would be very unbecoming in me to speak. But I cannot resist saying, that it has been with much pleasure that I have perused, and to a certain extent studied, the last published Memoirs in each of the three departments of the Survey. Though it was most pro-

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bably intended, when the survey commenced, that the chief, perhaps the exclusive, object was merely to indicate on maps, aided by descriptive memoirs, the general nature of the strata prevailing in different districts, and to give detailed explanations of those containing economic minerals—such as coal, lime, ironstone, shale, good building stones, brick slags, and so forth—the officers in later years have not confined themselves to these subjects, but have scrutinised the strata, and also the geographical features of the districts containing these strata, scientifically and theoretically, with the view of discovering the period of the earth's history when these strata were formed, and these geographical features imprinted, and to investigate the various forms of animal and vegetable life which existed in our country during primeval times.

Take, as an example, the last Memoir published in the English department of the Survey describing the geology of the neighbourhood of Cambridge, which I now hold in my hand. This Memoir, consisting of 184 pages, and illustrated by numerous maps, sections, and woodcuts, very properly describes at some length the strata worked for economic purposes, such as beds of coprolites, chalk, and various kinds of clay employed for bricks and tiles. The agricultural value of the phosphatic and calcareous beds is also pointed out. Information is then given regarding the nature of the various marine creatures whose remains have left these stores of phosphates, and also the circumstances which brought about in the eastern counties so large a deposition of calcareous matter. Lastly, the clay beds lying above the older strata are described, and views are offered on the question which we in Scotland still consider an unsolved problem—viz., the origin of boulder clay; for it seems that this perplexing deposit occurs in Cambridgeshire pretty thickly in many places. In reading that part of the Memoir, I was not a little pleased to find that the author adopts the idea I have myself long entertained that the boulder clay is a marine deposit due to the action of floating ice; an explanation which he states has the concurrence of Professor Ramsay, the Director-General of the Survey.

The passage is as follows:—"After a careful consideration of the evidence and study of the clay itself in very many sections, we are convinced that *coast-ice* has been the main agent in its formation. This has ground down and mixed up the material of the shores subjected to its action, and incorporated with it other material brought by itself from some near locality, or by icebergs from a distance. It has pounded up the mass again and again, rounding the softer pebbles, but making little impression on the harder; and it has, by repeated shiftings, moved

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debris from the lowest to the highest points now under consideration; and it has been aided in this by its work being done on a *sinking* area, every part of which was in turn subjected to its influence."

"After the completion of the MS. of this Memoir, our colleague, Mr Sketchley, strongly advocated the theory that the boulder clay was formed beneath *land-ice*. Notwithstanding his assertions, however, we are still convinced, that the arguments *in support of a coast-ice* origin have the advantage.

"We are pleased now to find, that our views are in accordance with those of our Director-General, Professor Ramsay, who quotes Professor Hind's account of the action of '*pan-ice*' (coast-ice) and the formation of boulder-clay, and observes that as the British Islands during the glacial epoch were more than once much in the same state as the north of Labrador, there can be little doubt that some of the British phenomena were produced by the same causes."—*Memoirs of English Geological Survey for* 1881, page 120.

The most recent Memoir published by the *Irish* Survey, and written almost entirely by Professor Hull, the Director of the Survey (as the preface to it bears), applies to a district where unfortunately no rocks or minerals of economic value have yet been discovered—viz., the county of Down, in the north-east of Ireland. The most important feature of the district is the great range of hills called the Mourne Mountains, reaching to a height of 2800 feet, and bearing, in structure as well as aspect, "a striking resemblance to those of the island of Arran in Scotland." The Memoir naturally is occupied chiefly with descriptions of rocks interesting only to the geologist.

I note a few points, as they illustrate the scientific spirit in which the subject is handled.

In one of the valleys running up into the Mourne Mountains, called the Kilkeel Valley, "there is the appearance of a remarkable terrace at an altitude of about 1200 feet above the sea-level," and of which terrace a striking diagram is given on the same page of the Memoir. "Similar terraces have been observed in several other mountainous districts (such as that at Killary Harbour) and they not improbably indicate old sea-margins."—Page 11.

"The drift-deposits rest in nearly horizontal positions against the flanks of the valleys, gradually ascending with the valley up to considerable elevations. Thus these deposits, consisting of sand, gravel, and clay, are found rising, in various valleys here enumerated, from 1200 up to 1550 feet."

The Boulder-clay question is also in this Memoir alluded to, though not so closely or fully discussed as in the English

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Memoir; and a different solution of the problem is assumed. "This deposit" (the Memoir says) "is now recognised by geologists as owing its formation to an *ice-sheet*, the stones and boulders it contains, indicating the direction from whence the ice-sheet moved. In this district, the general direction of the ice-movement seems to have been from the north or north-west. The boulder-clay ascends to a high level. The valley of the Bloody Bridge River has been filled with this material, out of which the existing channel of the river has been excavated. Ascending this valley, we find the stony clay with large boulders, assuming the character of moraine matter, and stretching up to the base of the steep slope to a level of about 1500 feet above the sea. Mr Traill, with myself, determined the upper limit of the deposit here to be about 1570; so that we may assume that only the highest elevations of the Mourne Mountains were left uncovered by the ice-sheet—*if indeed there were any such.*"—Page 19.

The last words of this sentence seem, notwithstanding what was said a little before, to imply doubts in the mind of the author of the Memoir as to the soundness of the ice-sheet theory.

When the granite rocks of the Mourne Mountains are described in this Memoir, I was interested in noticing that one variety contains occasionally, as a constituent mineral, "*the topaz;*" for two years ago, when on the west coast of Cantyre, within sight of Ireland, I found a block of granite differing from any I had ever seen before. It was so peculiar that I brought home a large chip, and submitted it to Professor Heddle for examination. His report was, that it resembled the granite of the Mourne Mountains, especially because he saw that the chip contained a crystal of topaz.

If this block of granite really came across the Irish Channel from the north-east of Ireland to Cantyre, it adds a link to the chain of evidence indicating the transport of rock fragments by floating ice.

As examples of the Memoirs issued by the Scotch Geological Survey, I produce the two last which have been published. One of these, published in 1878, is applicable to the 4th square in the index map, embracing parts of two counties, viz., Wigtown and Kirkcudbright. The other Memoir, published in 1879, is applicable to the 31st square, and embraces portions of the counties of Stirling, Lanark, and Linlithgow.

This last-named Memoir is one of extreme interest. It consists of 84 pages, of which the last 25 contain a list and description of fossils, and the localities where found. The first 58 pages are devoted to an account of the various rock forma-

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tions in the district, and of the useful minerals obtained in them. Professor Geikie, in his Preface, says that "the map, of which the following pages are an explanation, embraces the richest mineral district of central Scotland—the great Lanarkshire and Stirlingshire coal-fields, stretching between Glasgow, Grangemouth, and Bathgate." "No detailed map of the area has preceded the present sheet of the Geological Survey, in which, for the first time, the coals, ironstones, and limestones, with their sinuous outcrops and numerous faults, are delineated; and the area and structure of the surrounding older formations are correctly traced."

In this Memoir, the geographical features of the district are first described; then its geological structure generally is indicated; followed by an enumeration of the various formations—beginning with the sedimentary—then the igneous, and ending with the superficial deposits.

A particular account is given of the various limestones which are worked—so useful for agricultural and building purposes; and of six or seven separate coalfields, with the strata of coal, ironstone, and shale or fireclay which these coalfields contain.

In describing the *Igneous* rocks of the district, an account is given of those which form sheets or coulées, and those which fill fissures in the earth's crust; the usual direction of these fissures being east and west.

In reference to the superficial deposits, consisting of gravel and boulders, it is observed that the general carry has been from the north-west—but that in consequence of the obstruction of the Campsie Hills, there was a change in the direction of the current—the flow turning round to more or less east, varying between E 10° or 15″ N., and E 10° or 15″ S.

The boulders composed of rocks foreign to the district, are unhesitatingly referred to Highland tracts towards the N.W., being the nearest locality for these rocks—a view which it is said, and truly said, corresponds with the direction of the striae on the smoothest surfaces of the rocks.

In this part of the Memoir, the transporting agent is only generally referred to, as "*ice*," which we are told entered the district from the north-west, and after crossing the high ground of the Campsie Fells, turned upon itself and flowed more or less east (p. 48). Again it is mentioned, "that *the ice* which glaciated the rocks and formed the boulder clay, flowed from the Highlands, crossing in its course the Hills of Menteith," &c. But I do not see in this part of the Memoir any indication of the *kind of ice* which acted in this manner—*i.e.*, whether it was glacier, ice-sheet, or floating-ice. In a later part of the Memoir (page 53), reference is made to beds of gravel and clay forming

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a terrace reaching to a height of about 100 or 120 feet above the sea level, and which beds, it is said, "would seem to have been laid down when the land stood 100 feet below its present level." It is mentioned, that in these beds, "striated stones" occur from 6 to 8 inches across in size, which "look as (if) they had been drifted away and been dropped by *floating ice.*" It is farther stated, that "several of the clay seams (in these beds) are crumpled up in a wonderful manner; great sheets of them being rolled over and over, and involving the associated sands for considerable horizontal distances. This would seem to point to the *stranding* of *sheet pack ice*, on the sand and mud banks of that period."

The references which I have made to the Memoirs issued by the three departments of the Survey will, I have no doubt, satisfy you, as they have satisfied me, of the extreme value of these Memoirs, on account of the large amount of useful practical information they contain, and of the valuable scientific and theoretical suggestions embodied in them.

It would be wrong in me to omit special notice of the immense number of fossils collected by the officers of the Survey, in each of the three divisions of the kingdom, and which will in time afford ample materials for pictures of life in former ages of the world. During the last three years, the numbers of fossils collected, as shown in Professor Ramsay's printed reports, were, for England, 5618, Ireland, 3659, and for Scotland no less than 10,387. In each division of the Survey, one official acts as paleontologist, to study and identify the families, genera, and species to which the fossils belong, or else to point out that they belong to no known genera or species, and for which new names must be invented. It is very gratifying to see that in Scotland the number of fossils collected during the last three years is nearly double the number collected in England, though England is two-thirds larger in area, contains a far greater number of fossiliferous formations, and has engaged on it, for its survey, a staff of field geologists four times the number of those in Scotland.

The latest Memoir published in the Scotch Department consisting of 84 pages, has no less than 26 pages, or nearly one-third of the entire Memoir, devoted to fossils; and since its publication, communications have been made to different societies, as well as to newspapers, describing the fossil discoveries by the officers of the Survey. In a recent number of the scientific newspaper *Nature*, there is a leading article by Professor Geikie, describing the wonderful paleontological discoveries made among the carboniferous strata of Eskdale and Liddesdale, consisting of creatures, marine and terrestrial. The

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marine comprise fish and crustaceans; the terrestrial, scorpions, for such is the name given to them on account of their close resemblance to those animals now existing, and known under that name. Specimens of these scorpion fossils, as well as of others collected in the same locality, were kindly exhibited at a meeting of our Society last winter, when I happened to be present; and a Memoir by Mr B. N. Peach, the acting paleontologist of the Survey, describing the crustaceans, was last winter communicated to the Royal Society of Edinburgh.

I must allude to another kind of work which seems peculiar to the Scotch Department of the Survey—viz., the microscopic examination of rocks. Professor Ramsay, in his report to Government for 1879, mentions that "Professor Geikie has continued the microscopic examination of rock specimens collected in the field. 469 slices have been prepared in his office; and in addition, he has had a large series of slices prepared from various stages for the purpose of comparison."

In his report for the year 1880, Professor Ramsay says that "cut sections of the rock specimens collected, to the number of 333, have been prepared in the office, illustrating the structure of the igneous rocks in the south of Scotland, and of the crystalline schists and other rocks of the Highlands; and as before, Professor Geikie continues his microscopic investigation of them."

I am glad to have had it in my power to give this information regarding the work of the Scotch Geological Survey; as it must be gratifying to all who are interested in Scotch Geology to see the assiduity, diligence, energy, and success of the officers engaged on it. Not only are the usual paths of research actively followed, but new lines of enquiry have been thought of and opened out, which are likely to lead to important discoveries.

There is only one thing to regret, for which, however, the Scotch department is not responsible—viz., the slow progress of the Survey towards the accomplishment of its original object—viz., a complete set of Maps and Memoirs explaining the different geological formations of the whole country. To find that it will yet take more than thirty years before the Scotch survey will be completed, whilst the English survey will be completed in three years, and the Irish survey in eight years, is, I must confess, rather disappointing. But what else could have been expected? The numbers of field geologists during the last three years have been as follows:—For England, 30, 27, 26; for Ireland, 12, 11, 11; for Scotland, 7, 7, 7. These figures I take from Professor Ramsay's printed returns.

The Irish and the Scotch surveys began together, viz., in the year 1866, at which time the staff of Field Surveyors was the

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same in each, viz., 6. In Ireland the number had been increased to 12 before the year 1878. In Scotland the number till 1877 was 6, but was then increased by 1.

Now, undoubtedly, the staff ought to have been always greater in Scotland than in Ireland, because of the more complicated character of its geology; and also because of its greater extent, and its numerous coal and ironstone fields, shales for oil, and other mineral products. Much more time is required for the examination of such districts as these, than is required for mapping and describing formations barren of any useful mineral products. Professor Geikie in his latest published Memoir which embraces the Lanarkshire and Glasgow coal-fields, states in his Preface to the Memoir, that to unravel the geology of these coal-fields "with their sinuous outcrops and numerous faults," and to trace correctly the area and structures of the surrounding older formations, the examination commenced so early as the time when Sir Roderick Murchison was Director-General.

Exactly three years ago, in this Society, I took notice of the slow progress of the Scotch survey, and suggested that, with the view of expediting it, the same steps should be taken as had been taken some years ago, for expediting the Ordnance survey. Petitions were presented to Parliament, in the House of Lords by His Grace the Duke of Buccleuch, and in the House of Commons by a Scotch member, asking for an increase of the staff of surveyors. In consequence of these petitions being well supported, an addition was made to the yearly Estimates.

During last summer, the subject of the Ordnance survey was again brought before the House of Lords, this time on behalf of certain districts of England, where maps on a large scale were much required. A case having been made out which received general support from independent members, Government, after taking time for consideration, and for consulting the officers at the head of the Survey, announced that £8000 would be added to the Estimates, to give what was asked for.

I suggest this as a precedent to be followed, in order to obtain for Scotland the same benefit which has been secured for England and Ireland, viz., an early completion of the Geological survey. It is wrong, however, for me to say that Scotland would alone be benefited. It is of *national* importance, that every part of the United Kingdom shall be surveyed, and maps and memoirs published as soon as possible.

I venture to think that our council might take this matter into consideration, and prepare a Petition to Parliament, which no doubt the Duke of Argyll would willingly present in the House of Lords, and some Scotch member in the House of Commons.

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In concluding these remarks, I will only observe, that considering how much remains to be done for completing the Geological survey of Scotland, members of Geological Societies ought to feel an additional incentive to help in the good work. It was at one time thought that the Geological survey would put an end to Geological Societies. In Scotland, at least, we see that there is ample time and space for researches by amateur Geologists, on ground not yet touched by any official Geologist. Even on ground which has been surveyed officially, there may be opportunity for revision, reconsideration, and correction, of which notable proof is afforded in the Irish Survey, where during the last two years no less than 2000 square miles have had to be revisited by officers set apart for the purpose, and employed on that work alone.

To Her Majesty's Secretary of State for the Home Department.

The Memorial of the Edinburgh Geological Society.

Sheweth,—That in or about the year 1854, the Geological Survey of the United Kingdom was commenced.

A separate staff was formed in each of the three divisions of the Kingdom.

The work undertaken was of the same nature in each division, viz., 1st, Surveying the different districts by persons selected for their knowledge of rocks and minerals. 2nd, Representing on maps and sections by different colours, the various rock formations, and the line or direction of veins or fissures intersecting these formations; and 3d, Printing descriptive Memoirs, explaining in detail the nature of the strata in each district, as well as the economic uses to which these strata were put or were capable of being put.

In England, the survey is well nigh completed, there being only three or four counties, not of much mineral value, which have yet to be surveyed, mapped, and described. It is believed, that in about three, or at the most four years, the English survey will be finished.

In Ireland, the work is not so far advanced. It has been found necessary during the last two or three years to employ a certain proportion of the staff in re-examining districts in consequence of new views having been adopted, as to the nature of some of the formations in these districts. But it is expected, that in about eleven years, the first survey will be finished.

In Scotland, the survey matters have progressed much more slowly. Supposing that it goes on at the same rate as during

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the last few years, it is probable that it will take more than thirty years before it is finished.

The area of Scotland in square miles is about the same as that of Ireland; but the staff of field geologists occupied in surveying, mapping, and describing, has during the last ten or twelve years been smaller in Scotland than in Ireland, whereas it ought to have been greater, on account of the greater amount of work to be done in Scotland. Not only are the different geological formations more complicated, but the coal-fields, ironstone mines, shale strata, and other mineral works of that nature, are in Scotland more numerous and extensive, and require a large amount of minute examination. The fossil remains, so important in a scientific point of view, are also more varied in Scotland, and have necessarily more largely engaged the time of the surveyors.

No blame attaches to the officers on the Survey, for its slower progress in Scotland. On the contrary, the Memorialists would offer their humble testimony to the ability shown by these officers in striking out new lines of research, in carrying on most minute enquiries, and in recording everything with reliable accuracy.

The only cause of the slow progress is the insufficient number of surveyors and geologists allowed to the Scotch Survey, which it is hoped will be speedily rectified.

Your Memorialists need not point out how important it is, to have the Geological Survey of Scotland carried on more rapidly. As Parliament resolved on having a survey made, it must have been because it was to be not only of scientific value but of practical utility; and there can be no doubt that an accurate exposition of the different kinds of strata existing throughout the country is of great assistance in showing where useful mines and minerals may best be searched for and worked.

Your Memorialists therefore respectfully submit this matter to the consideration of Her Majesty's Government, and express a hope that steps may be immediately taken for increasing the staff of officers employed on the Scotch Geological Survey.

Reply to Memorial.

SCIENCE AND ART DEPARTMENT, LONDON, S.W.,
22*d March* 1882.

SIR,—With reference to your letter of the 9th instant, submitting to the notice of the Lord President a Memorial from the Edinburgh Geological Society, I am directed by the Lords of the Committee of Council on Education to call your attention to the

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statement of the Vice-President in the House of Commons on the 18th August 1881. You will see therefrom, that the mapping of the solid geology of England and Wales on the one-inch scale will, it is estimated, be completed in two and a half years from that time, when a considerable portion of the staff of the survey will be transferred to Scotland. It is proposed, on the completion of the English survey, to transfer seven officers from England to Scotland, when, it may reasonably be hoped, that the survey on the one-inch scale of the solid and superficial geology of Scotland will be completed in eleven years.—I have the honour to be, Sir, your obedient servant,

W. D. CONNELLY,

W. I. MACADAM, Esq., F.C.S., F.I.C.,
Edinburgh Geological Society,
Surgeons' Hall, Edinburgh.

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II.—*First Notice of a Post-Tertiary Shell-Bed, at Clava, in Nairnshire, indicating an Arctic Climate, and a Sea-Bed at a height of* 500 *feet.* By JAMES FRASER, C.E., Inverness.

(Read 17th November 1881.)

OLD CLAY PIT.

The subject of the following notes is an old clay pit on the farm of Drummore of Clava. The pit is at the base of a broad terrace, about 70 feet in height, and has not been used for about thirty years; and the stratum of clay containing the shells has been covered by a landslip for more than twenty years, until the author succeeded in exposing the shell-bed by an excavation through the overlying earth in June last (1881).

SITUATION OF SHELL-BED.

Clava is situated on the east side of the river Nairn, and about six miles due east of the town of Inverness; and the shell-bed is half a mile east of the river, and nearly 200 feet above its level. The spot is shown on Mr Richardson's map, p. 200 of this volume. The accompanying section across the valley of the Nairn, and passing through the spot where the shells are found, shows the geological position of the shelly deposit. Another section, on a larger scale, gives an enlarged view of the shell-bed itself, and of the face of the terrace above it. The shelly deposit appears to lie on the eastern margin of the Old Red Sandstone formation, which extends in a south-westward direction from it.

PARALLEL RIDGES.

The terrace under which the shelly deposit has now been exposed corresponds with the upper one of the "two long gravel ridges with marshy hollows behind them, that run parallel with the river on the east slope of the valley," as described in the author's paper on the "Recent Formations and Glacial Phenomena of Strathnairn," at page 62 of the "Transactions of the Edinburgh Geological Society," 1881. At the point where the shells occur the broad terrace extends back to the hillside, and thus forms a break in the general line of the hollow behind the upper one of these parallel ridges. The lower, and smaller, ridge is that which is followed for a considerable distance by the district road, and is composed, generally, of a later gravelly till, but based, at some points—especially near the bridge of the Dalroy Burn—on a mass of true boulder clay.

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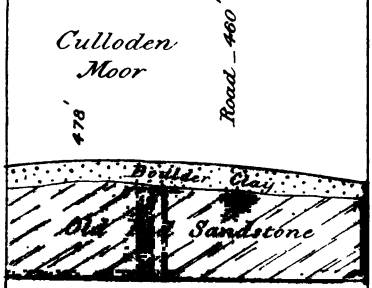
SECTION ACROSS THE NA
AT CLAVA.



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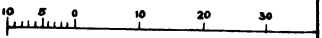

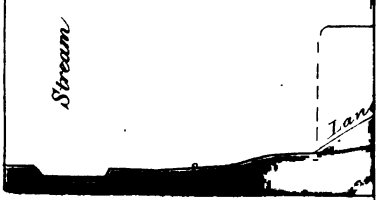

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Description of Strata.

Boulder Clay.—Referring to the enlarged section of the face of the terrace at the shelly deposit:—the top is composed for a depth of 40 or 45 feet of yellowish boulder clay, having a covering of soil with a gravelly subsoil. This boulder clay—geologically so called—consists of a mixture of gravel, sand, and stones, with a small proportion of clay, and containing fragments of Old Red Sandstone, and of gneiss and its allies, in nearly equal proportions, many of the sandstones being finely scratched. A small stone, distinctly but irregularly scratched, was submitted to the Society with these notes, along with samples of the shells and clays.

Sand.—The boulder clay gradually passes downward into a bed of fine yellowish sand, about 20 feet in depth, and showing marks of stratification. This stratum of sand has not yet been found in the exposed faces of the terrace, east or west of the shell-bed. In every other spot, on the same level, the terrace seems to consist of boulder clay. This, however, may be owing to the difficulty of getting complete sections exposed to view. The fine sand is compressed into an exceedingly hard mass for about 4 feet from the bottom, but is more friable above that height. An experienced and skilful moulder in Inverness has tested a small quantity of this sand for iron casting, and has found it to be of a very fair quality, although its suitability for fine moulding cannot be held as established until a larger quantity of it is tried.

Shelly Clay.—Below the bed of fine sand just described is found the shelly deposit, consisting of a stiff blue clay, or silt, which is rather more friable and sandy from 4 to 5 feet below the surface, and again firmer below that level. The line between the blue clay and the fine sand above it is sharply marked. A depth of 5 feet of the blue clay has been exposed, and from 2 to 2½ feet more bored with an iron bar, followed by a tube of smaller diameter, without reaching the bottom of it; so that the shell-bed is, at least, from 7 to 8 feet in depth. The author has not yet been able to find the same deposit at any other point, nor to ascertain what it rests upon. The section across the valley shows the general arrangement of the rocks in the locality; and, at the shell-bed, the succession of strata, beginning at the top, is as follows:—

	Feet.
1. Soil and gravel, } 2. Boulder clay, }	50
3. Fine sand, stratified, . . .	20
4. Shell-bed of blue clay, bottom not reached,	7½
5. Boulder clay?—not seen, . .	?
6. Old Red Sandstone, . . .	?
7. Silurian Gneiss, . . .	—

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The Shell-Bed.

The blue clay contains a slight proportion of small stones, finely polished, and mostly well-rounded and water-worn, and all, unless with very few exceptions, consisting of gneiss rock. The shells are most plentiful at a depth of about 2 feet from the surface of the clay; and none have as yet been found at the surface, nor among the fine sand or boulder clay overlying it. A careful search has been made in the boulder clay in the immediate neighbourhood for fragments of shells, but without success. Many of the shells are quite entire, although in a very delicate condition; and there is no doubt whatever that the shells are *in situ* in this bed. The delicately preserved condition of their epidermis, or outer skin, and of their markings, proves that they have been subjected neither to glaciation nor abrasion of any kind.

Heights above Sea Level.

The height of the shell-bed has been verified by the author, by actual measurement from one of the levelling bench marks of the Ordnance Survey; and the height of the top of the shelly clay is found to be 501 feet, and the top of the fine stratified sand 520 feet, above Ordnance Datum, or average sea-level. The top of the terrace, at the same place, is about 570 feet above sea-level. This appears to be the highest marine deposit of the same geological age yet found in the north. The only other case in Scotland where a shelly deposit of the kind has been found as much as 500 feet above the sea is that of the shell-bed near the Monkland Iron Works, at Chapel-hall, Airdrie, Lanarkshire, described by the late Mr James Smith, of Jordanhill, in 1850, as being 510 feet above the high water level of the sea, by barometric measurement, which is not to be relied on for minute accuracy.* The Rev. Henry W. Crosskey, F.G.S., Birmingham, then of Glasgow, in his paper on the Airdrie bed,† gives the height of it as 526 feet, his information having been derived from Mr Russell, who originally discovered the shells. Mr M. Æ. MacBean, C.E., of the Public Works Office, Glasgow, has kindly ascertained for me that the exact height of this shell-bed is 518½ feet above average sea level, the surface of the ground being 532½ feet. Mr Crosskey tells us that the shelly stratum was only 2 feet thick where it was pierced through, and that only two species of shells were found in it—*Tellina calcarea* and *Cyprina Islandica*, and a *Balanus*, or barnacle.

Fossils of Shell-Bed.

The character of the shelly stratum at Clava will be best

* See Mr Smith's paper in his "Researches in Newer Pliocene and Post-Tertiary Geology," pp. 17 and 141, and "Proceedings of Geological Society," vol. vi., p. 386.

† See "Proceedings of Geological Society," vol. xxi., p. 219.

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understood from the lists of its fossils kindly furnished to the author, first, by Mr Thomas F. Jamieson, F.G.S., of Ellon, Aberdeenshire, and afterwards by Mr David Robertson, F.L.S., F.G.S., Glasgow, and from the analyses of the clay and overlying sand kindly prepared by Mr W. Ivison Macadam, F.C.S., F.I.C., Edinburgh, all of which are given below.

(1.) *Shells.*

I.—*List of Shells identified by* Mr JAMIESON, *in the samples of the clay first taken up.*

1. *Mytilus edulis*, or common mussel—fragments.
2. *Littorina litorea*, or common periwinkle—most plentiful species.
3. *Littorina rudis* (Maton)—one specimen.
4. *Leda pernula* (Müll.)—several, some of them complete with epidermis, but crushed.
5. *Natica Grœnlandica*, or *N. Pallida*—several examples, but mostly crushed.
6. *Mangelia* [or *Pleurotoma*] *turricula* ( )—one specimen.
7. *Nucula tenuis* (Mont.)—a few specimens.
8. *Tellina Balthica* (Linn.)—three or four, and fragments.
9. *Buccinum undatum* (Linn.)—fragments of several, size not large.

II.—*List of Shells identified by* Mr ROBERTSON, *in samples of clay last dug out.*

1. *Mytilus*, sp.—fragments.
2. *Littorina litorea* (Linn.)—common.
3. *Littorina rudis* (Maton)—two examples.
4. *Leda pernula* (Müll.)—fragments.
5. *Leda pernula*, var. *macilenta* (Steenst.)—one and a valve.
6. *Leda pygmæa* (Münst.)—one example.
7. *Natica Grœnlandica* (Beck.)—moderately common.
8. *Pleurotoma turricula* (Mont.)—two young examples.
9. *Nucula tenuis* (Mont.)—one example and a valve.
10. *Homalogyra atomus* (Phil.)—one example.
11. *Trophon clathratus* (Linn.)—one, in pieces.
12. *Cardium edule* (Linn.)—a small fragment.
13. *Astarte compressa* (Mont.)—one example.

By comparing the above two lists together, it will be seen that no less than fifteen different kinds of shells have been found in this shell-bed.

(2.) *Microzoa.*

Mr Jamieson found by a partial examination of the clay sent to him one example of *Balanus*, and some *Foraminifera* of the

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genus *Polystomella*, or *Nonionina*, but he did not further pursue the search for minute organisms. Mr Robertson, who made a full examination of some of the clay, has not found a great variety of *Foraminifera* or *Ostracoda;* but those he has found are such as occur in the glacial clays of the west of Scotland. His first search gives the following:—

Foraminifera.

1. *Quinque loculina seminulum* (Linn.)—one broken example.
2. *Lagina Marginata* (F. & M.)—one example.
3. *Lagina hexagona* (Will.)—one example.
4. *Polymorphina lactea* (W. & T.)—moderately common.
5. *Polymorphina acuminata* (Will.)—rare.
6. *Uvigerina angulosa* (Will.)—one example.
7. *Polystomella striato-punctata* (F. & M.)—moderately common.
8. *Polystomella artica* (P. & J.)—moderately common.

Ostracoda.

1. *Cythere pellucida* (Baird)—three valves.
2. *Cythere viridis* (Müll.)—rare.
3. *Cythere lutea* (Müll.)—two valves.
4. *Cythere castanea* (G. O. Sars.)—rare.
5. *Cythere angulata* (G. O. Sars.)—two valves.
6. *Cytheridea punctillata* (Brady)—moderately common.
7. *Cytherura striata* (M. Sars.)—two whole examples.
8. *Cytheropteron latissimum* (Norman)—rather rare.
9. *Cytheropteron nodosum* (Brady)—moderately common.

Cirripedia.

1. *Balanus crenatus* (Brug.)—small and rare.
2. *Balanus balanoides* (Linn.)—rare.

It may be stated here, that Mr Robertson has made a careful examination of two samples taken at different depths from the fine sand above the shelly clay without finding a vestige of a marine organism in it. He remarks that both the sand and the blue clay are full of mica scales, with this difference that they are tinged with yellow in the sand, while those in the clay are white.

ANALYSES OF CLAYS.

The following are the analyses of the shelly clay or silt, and of the sand bed above it, and also of a mass of very strong and fine yellow clay, found under the boulder clay about 100 yards south of and on the same level as the shell-bed, kindly prepared, as has been stated, by Mr W. Ivison Macadam, the Honorary Secretary of the Society, whose interesting and valuable remarks in connection with the analyses are also given.

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"*Analyses of Samples of Clay received from* JAMES FRASER, Esq., C.E., *Inverness.*

"SURGEONS' HALL, EDINBURGH,
14th November 1881.

	The Shelly Clay or Silt.	Compressed Sand above Shelly Clay.	Upper part of Sand above Shelly Clay.	Clay under Boulder Clay.
"*I.—Soluble in Acid—*				
Ferric oxide, ...	4·763	3·397	4·172	17·234
Aluminic ,, ...	0·746	0·385	0·353	0·486
Calcic ,, ...	0·839	0·371	0·316	0·282
Magnesic ,, ...	0·691	0·502	0·368	0·457
Sulphuric anhydride, .	0·212	0·102	0·101	0·148
Potassic oxide, . . } Sodic ,, . . }	0·179	0·112	0·108	0·121
Carbonic acid, &c., .	1·404	0·845	0·672	0·747
	8·834	5·714	6·090	19·475
II.—The residue after fusion with an Alkaline Carbonate yielded—				
Ferric oxide, ...	6·739	5·975	6·672	14·402
Aluminic ,, ...	8·077	7·718	2·203	0·647
Calcic ,, ...	0·614	0·620	0·191	0·461
Magnesic ,, ...	0·428	0·380	0·227	0·270
Silica, ...	70·192	75·737	83·605	60·789
	86·050	90·430	92·898	76·569
Water, ...	5·116	3·856	1·012	3·956
	100·000	100·000	100·000	100·000

"*The Shelly Clay or Silt* is similar to clays found in other parts of the Highlands, and bears a close resemblance to clays obtained from mixed gneiss and schist districts.

"*The Compressed Sand above Shelly Clay* is a mixture of the above clay with a large proportion of sand.

"*The Sand above Shelly Clay* has a composition similar to ordinary sea sand.

"*The Clay under Boulder Clay* is very peculiar on account of the extremely large proportion of iron, part of which is present as oxide and part as silicate. It is not a clay, strictly speaking, but a sand bound together by the iron.

"From the above results, I am of opinion that the 'shelly clay or silt' ranks as a true Arctic clay, and as such will yield good results.

"W. IVISON MACADAM, F.C.S., F.I.C., &c.,
Lecturer on Chemistry and Analytical Chemist."

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Conclusion.

The Arctic character of the deposit is established by the presence of the *Leda pernula*, *Leda pernula* var. *macilenta*, and *Natica Groenlandica*, all of which are decidedly Arctic.

That this shell-bed, again, represents a part of the sea-bed, not far from the shore line, seems to be as clearly shown by the abundance of the *Mytilus* and *Littorina litorea*. It is differently with the Arctic shell-beds at a lower level at Gamrie and King Edward, near Banff, where, as Mr Jamieson has pointed out, the shallow water shell, *Littorina litorea*, so plentiful at Clava, is entirely absent.

Dark marbled streaks, which are thought to be traces of sea-weeds, can be seen in portions of the shelly clay, when the lumps are freshly broken.

The author regrets that he has not been able to ascertain, with any degree of certainty, what the shelly clay rests upon, nor the extent of it; but he hopes, at some future time, to extend his observations on the ground.

In parting with the subject, the writer begs to express how very much he is indebted to the gentlemen whose names have been mentioned in this paper, and to others, for their great kindness and readiness in furnishing him with information, and that at no small amount of trouble to themselves.

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III.—*Shells in Glacial Clay at Fort-George, Inverness-shire.* By THOMAS D. WALLACE, F.R.S.A. Scot., Head Master, High School, Inverness.

(Read 17th November 1881.)

In a paper on "Recent Geological Changes on the South Shore of the Moray Firth," which I had the honour to read before the Society in January of last year (1881), and which will be found in the "Transactions" of the Society, vol. iv., part i., page 45, mention was made of deposits of clay on the south shore of the Moray Firth. One of these is a deposit of blue clay or mud at Ardersier, containing numerous fragments of shells.

As Mr Fraser, C.E., Inverness, has just brought under your notice a most important discovery of similar clay with shells, at Clava in Strathnairn, I thought that it might be interesting to submit a few notes regarding the clay at Ardersier.

The deposit in which the shells are found lies under a mass of ordinary yellow boulder clay, and consists of a blue tenacious mud, containing very few boulders. While the shells are found throughout the whole mass, they are more numerous where the mud is mixed with sand and small pebbles.

The clay is to be found exposed in the front of the terrace facing the sea, about a quarter of a mile east of the Manse of Ardersier. The height of the whole exposed section is from 25 to 30 feet, and the exact position in which the shells were found is 30 feet above the average sea level. Top of blue silt is from 10 to 15 feet below the top of the terrace.

Specimens from this section were examined by Mr Jamieson of Ellon, Aberdeenshire, who found shells there in 1865.

Among those examined, then and afterwards, Mr Jamieson found the following:—

1. *Leda pernula*—a really Arctic shell, and not now found on the British coast.

2. *Tellina calcarea*—another Arctic shell, not now found in British seas.

3. *Astarte elliptica.*

Some more specimens were obtained and forwarded to Mr David Robertson, F.L.S., Glasgow, who reports as follows:—

"I have looked over the material, and, singular to say, although there are many fragments of shells, so far as I have seen they all belong to one species, *Astarte sulcata;* and although there is only one whole valve among the fragments, the shells do not seem to be falling asunder from unusual brittleness or erosion, as they are still comparatively strong. Many of the fragments

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were in natural position, embedded in the clay, and it will be observed that none of them are water-worn. The *Microzoa* appear to be also poor in species. I am sorry there has not been time to work it out more fully.

"The following are the prevailing forms:—

Ostracoda.

Cytheridea punctillata (Brody)—common.
„ *papillosa* (Bosquet)—rare.
„ *Sorbyana* (Jones)—rare.
Cytherura Sarsii (Brody)—two valves.

Foraminifera.

1. *Polymorphina lactea* (W. & T.)—moderately common.
2. „ *asummata* (Will.)—two examples.
3. *Polystomella striato-punctata* (F. & M.)—common.
4. „ *Arctica* (P. G.)—two examples.

"There is one small plate of *Balanus crenatus* (Brug.).

"All the fossils obtained, in this sample of clay, are more or less common in our Scottish Post-tertiaries, as well as in our neighbouring seas. It is not unlikely, however, that further research will bring to light some of the more characteristic Arctic shells. DAVID ROBERTSON."

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IV.—*Notes on a Sand Covered District on the East Coast of Aberdeenshire.* By WILLIAM FERGUSON of Kinmundy, F.L.S., F.G.S., F.R.S.E., *V.P.* Edinburgh Geological Society.

(Read 13th December 1881.)

The great sand-blown tract known as "The Sands of Forvie" lies immediately to the north of the mouth of the river Ythan, which flows into the German Ocean about half-way between Aberdeen and Peterhead. To the south of Ythan mouth there are also large accumulations of blown sand, especially in the parishes of Belhelvie and Foveran, where tradition says that a large extent of what was once ploughed land was covered up in one night.

I propose, however, at present to confine my notes chiefly to the district already indicated to the north of the Ythan, where a complete parish has been obliterated, its arable fields being now covered, in some places to an enormous depth, by great drifts of sand.

In such a region of legend and mysterious story as the north-east of Scotland, it was not likely that such an event as this would be uncommemorated by some local tradition, and the story is that the destruction of a once fertile estate was owing to a curse pronounced upon it by an heiress unjustly dispossessed of her inheritance. It is said that the ruthless despoiler placed his unfortunate victim, his own niece, in a boat and sent it out to sea, and that the last sound heard from it was a wail, the burden of which is preserved in this distich :—

> "Yf evyr maidenis malysone
> Dyd licht upon drie lande,
> Lat nocht be funde on Forvy's Glebys,
> But thistle, bente and sand."

Whatever may be thought of the weird story, it is true that to-day, over an expanse of some four miles in length and of from two to three in breadth, there is now a remarkable waste, which was thus described by a writer in the *Aberdeen Magazine* for May 1832 :—

"The scene was more in accordance with the desolation of an African wilderness than the blue hills and green valleys of my native Caledonia. No trace of human habitation could be seen: huge piles of driven sand, stretching for miles in every direction, presenting no vestiges of life or vegetation but the bent under our feet, and it may be a stray sea gull over our heads, might have led us to realise the feelings of loneliness, which the

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traveller might be supposed to experience in the vast desert of Sahara."

The sand hills commence on the north bank of the Ythan, which now, says Dr Pratt, "for about a quarter of a mile from its mouth, is hemmed in by vast sand banks within narrow bounds; but a little higher up, the stream expands into a spacious basin, averaging, at high water, 600 yards in breadth; and with its many creeks and inlets is, in some places, nearly a mile. The length of the pool is about 3 miles; hence, at a moderate calculation, the quantity of water which at spring tides—allowing an average depth of 6 or 7 feet—issues from the neck of the river, is about five or six millions of cubic yards every six hours. It may therefore be imagined with what terrific impetuosity the water, on the retrocession of the tide, forces its way back into the ocean."

I mention this, because you will easily see from this statement that the currents of this tidal river must greatly influence the changeful character of the vast accumulation of sand at its mouth.

I may quote all that I have been able to gather of the history of this event.

Dr Pratt, App. Buchan, p. 356, 4th edit., says:—"That a great part of the parish was overblown before 1688 may be asserted; for, in the MS. ascribed to the Countess of Erroll, of a date anterior to that year, it is said that the parish of Forvie 'is wholly overblown with sand.' It is said that in a book entitled 'The Acts of the Church,' printed in black letter in London about the year 1570, the author of which is a Mr Masson, who designates himself 'Preacher of the Gospel,' the remark is made that 'the folks of Forvie suffered this heavy judgment because they were papists and grossly ignorant.' I have not been able to obtain a sight of this work, and cannot therefore vouch for the accuracy of the quotation, any more than I can do for the credibility of the following traditions, still current in various parts of the district, viz., that on the 10th day of August 1413, Aberdeen was visited by a storm of wind and rain from the east, which lasted many days, and in violence far surpassing anything of the kind the oldest inhabitant had ever witnessed. The sea heaved in great quantities of sand from the Dee northwards, but especially about the mouth of the Don, which for some time was entirely blocked up, damaging many houses in and about the city. Along the coast to the northwards great damage was done, and many lives were lost by the falling of houses and the drifting of the sand. The overblowing of the parish of Forvie is ascribed to this storm.

"Another tradition in reference to the same storm states that this tempest continued for nine days without intermission. A

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small vessel freighted with slates had just arrived in the Bay of Rattray, where she lay at anchor during the storm. In the meantime, the sea had thrown up a solid bank of sand across the mouth of the bay, rendering the ship completely land-locked, and what was formerly a beautiful bay is now the Loch of Strabeg.

"These traditions acquire probability from the following historical statements. It is said that Herenbauch, in his History of Iceland, translated by M. Deppel, mentions that 'on the 10th day of August 1413 this island (Iceland) was visited by a tremendous hurricane which lasted many days, during which Heckla burst into an eruption, and eighteen farms were destroyed in one day. Many people perished, besides horses and cattle which were destroyed by floods of water rushing from the mountain, occasioned by the melting of the snow and the ice in the vicinity of the crater.'

"A French author, whose name has not been given, seems to corroborate this story. 'On the 10th of August 1413 a whirling column of black smoke of awful aspect, and with a hissing noise heard for many miles, issued from the crater of Mount Vesuvius. It rose to a great height, and after a short time was again drawn back into the mountain. At or near the same time Calabria was shaken to its centre by an earthquake, and many thousands of its inhabitants perished.'" Thus far Pratt.

Mr Jamieson, F.G.S., says:—"The coast at Forvie and Foveran is remarkable for one of the largest accumulations of blown sand to be seen in Scotland, an accumulation which must have been the gradual result of existing causes operating continually since the establishment of the present coast-line. The drift has been chiefly to north and north by west, caused by the influence of the southerly winds."

From the pier at Aberdeen to the mouth of the Don the distance is 12,000 feet or 4000 yards, a little over 2 miles. All along this part of the shore there is a broad space or links of varying width, but at the broadest about 2000 feet or 660 yards, called "The Old Town Links." The character all along is high sand-hills say from 30 to 50 feet high close to high water, and then a flat sandy space inside, largely overflowed at high tides.

Immediately north of the mouth of the Don this sandy margin is about 1000 feet broad, and rises to a height of about 46 feet. From the mouth of the Don to the mouth of the Ythan is a distance of about nine and a-half (9½) miles, and the breadth of sand from high water-mark at each mile is as follows:—

	Feet.
1st mile, ...	1000
2nd do., ...	1250

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	Feet.
3rd mile, ...	1000
4th do., ...	1500
5th do., ...	1250
6th do., ...	1000
7th do., ...	1500
8th do., ...	1250
9th do., ...	1500

The height of the sand-hills all along may be taken as averaging (from the Survey) 50 feet. At some points the sand encroaches much further on the land than the distance I have specified. From the 9½ mile point, at the mouth of the Ythan, they reach west about 3000 feet, and north along the river they stretch a full mile, with a breadth of some 2000 feet.

But as soon as we cross the mouth of the Ythan we have a conical hill of bare sand some 50 feet high, and then the stretch of the Forvie Sands. From Ythan mouth to Collieston along the coast measures about 3½ miles. At 1 mile the breadth of sand is 3000 feet; at 2 miles, in the direction of east, it is 6000 feet; from the same point north-east, 8000 feet; and north, some 9000. The 50 feet contour line covers the southern portion of this great area, but it rises towards the centre to 100 feet, and towards the northern end to 145 feet. These heights are taken where the sand is not so deep. All round the coast it is blown to great heights, and towards Collieston especially the sand-hills reach very considerable altitudes. Hackley Head, which is a rocky promontory capped by a considerable thickness of tough red clay, rises to 115 feet. A path across the sands from Collieston to Waterside—*i.e.*, from north-east to south-west—gives these measurements from the Survey, 132, 117, 131, 145, 133, 100. About the centre of the sands the Bench mark of the Survey is 186 feet.

Throughout the waste there are several small lochlets, and one or two small rivulets gather the surface water and springs, and pour them over the cliffs in pretty cascades.

About 1½ mile from the Whiteness Inn at Collieston, as the crow flies, and at a distance of 750 feet from the edge of the cliff, are traces of the ruins of what was the parish church of Forvie. All that is to be seen now is a green spot among the surrounding sand-hills by the margin of a tiny streamlet. The place is so buried among the sand hills that it is somewhat difficult to find it. When you do reach it, the little oasis of green grass is a most refreshing relief from the trying yellow sand.

Of this old church the New Statistical Account says:—"The foundation of the old Kirk of Forvie is still visible, being the only vestige throughout the whole sands, commonly called the links, which indicates that this district was once the habitation

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of man. Graves have been discovered round it, but nothing found in them except a a few bones."

At the northern extremity of the sands, and close to the fishing village of Collieston, there is a loch called the Sand Loch, in the shape of the Greek letter gamma, Γ, of which the one arm is 1500 and the other 1200 feet long. It has become much smaller since I remember it by the gradual encroachment of the sand.

Some 3000 feet to the north-west of it is another loch called the Cotehill Loch. The level of the water in the Sand Loch is 111 feet, and that of the Cotehill 117 feet.

At some distance inland to the north-east is the Meikle Loch of Slains, surrounded by the Kippet Hills. These are interesting as having yielded fossils which indicate them to be the equivalent of the Red Crag. The surface of the water in the Meikle Loch is 134 feet. We read in the New Statistical Account:—"There are three lakes in the parish, and one of these, called the Meikle Loch of Slains, is really a magnificent sheet of water, covering, in the depth of winter, a basin of from 70 to 73 acres. It is surrounded on three sides by a ridge of land,—the Kippet Hills [perhaps the Caput or Heading Hills (?)] rising by an easy acclivity to the height of from 50 to 60 feet above the level of the loch. Its mean depth may be about 22 feet, but in one place it has been ascertained to be 52. The only outlet from it is by a small stream at the south end, which has been converted into a dam to drive a meal-mill about a mile below. The other two lochs, called Cotehill and Sand Loch, have evidently been formed by the drifting of the sands from Forvie, and each covers a space of about 15 acres." Thus far the Statistical Account. Dr Pratt, a local historian, has added: —"We must observe that since the publication of the above report, the outlet of the Meikle Loch has been lowered 4 or 5 feet, reducing to the same extent the level of the water. This considerably diminishes the fine sweep of the lake, and adds nothing to the land, as the borders are composed entirely of rounded shingle. It is evident from the appearance of its shores that, in former times, the loch occupied a much larger area."

When I first read a paper on the green sands of Aberdeenshire to the Glasgow Philosophical Society, about the year 1848, I fancied these hills round this Meikle Loch belonged to the green sand, and I thus referred to them:—"The first or southernmost point is about 2 miles inland from Collieston. The deposit takes the form of a ridge of hills surrounding three sides of a loch. This loch has been ascertained to be in one place 52 feet deep, and the hills rise round it to a height of from 40 to 50 feet. They are composed of gravel mingled with comminuted shells, and containing water-worn nodules of limestone, mica, slate, and gneiss. The limestone nodules contain organic re-

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mains. Our gardener, who collected my specimens, says that he broke the most he saw, but only found the remains in one. After deducting from the specimens of the sand and gravel sent me the recent Helices, there remained the debris of broken seemingly marine shells. The nodules are much water-worn."

Mr T. F. Jamieson says:—"Another interesting circumstance is the occurrence, in the parishes of Slains and Cruden, of some traces of the Red Crag gravel, one of the later tertiary beds not known in any other part of Scotland. These occur along the coast from Collieston to the old castle in Slains, and also in the adjoining district of the parish along the north side of the loch of Slains, and in some parts of Cruden. The age of this deposit is determined by the character of the fossil shells which it contains. It is further remarkable for containing numerous fragments of limestone, unlike any rock in this part of Scotland, and which one might suppose to have been derived from strata of the Permian group. The Slains farmers were formerly in the practice of collecting these lumps of limestone, and burning them for lime to their fields. Traces of fossils sometimes occur in them."

I paid a visit, along with two or three others, in the course of the past summer (1881) to the sands of Forvie. Leaving the fishing village of Collieston by the back of Whiteness Inn, we are at once on the coast-line. All along in this part it is characterised by low cliffs of gneiss, or mica schist, capped by varying thicknesses of red clay. The shore is indented with numerous small creeks and bays, and is very picturesque, and full of interest from its caves, and the infinitely varied shapes assumed by the rocks under the eroding influence of the great waves of the German Ocean.

Leaving the sea margin to our left, we lose ourselves instantly among the sand-hills, which here are numerous, isolated, and high. The path leads over colls between the higher eminences, and down into petite valleys where the sand has been blown quite off the soil, exposing the red clay subsoil. Wherever this is the case, a rich close herbage covers the ground, decorated with the yellow bed straw (*Galium*), the Scottish blue bell (*Campanula*), and other flowers. It is a fatiguing walk, this first portion of the route, for the sand is loose and shifting—the slope of the ascent is the angle at which such loose dry sand lies—your feet sink in it to the ankles, and so loose and moving is it that your footmarks are filled up almost as soon as you lift your foot.

When we have surmounted three or four of these sand-barriers, we enter an extensive wind-swept plain, with only here and there very slight eminences of sand. To the left, along the sea margin, the sand hills continue, and to the right a somewhat distant horizon is also lined with them; but a vast central space is tolerably level, covered with scrubby heath (*Calluna*), with large patches of berry heather (*Empetrum nigrum*). Here and

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there are boggy patches, almost lakelets, full of reeds, water ranunculus and other water plants. We crossed this plateau in search of the ruins of the old kirk, but though we had found it more than once on former visits, this time we failed to do so, it is so wonderfully hidden among the sand-hills near the shore. It is a wild and lonely scene, no human being visible, except along one beaten pathway, a long train of fishermen and fisher-women returning from a six miles tramp to Ythan estuary laden with mussels and lobworms for bait. But this track lies along the western verge of the sands, and when you leave it, even for a few yards, you are in the heart of a wild solitude, the haunt and home of great coveys of grouse, and innumerable rabbits.

We had rested to lunch on the sheltered side of a sand bunker (for it was a bitterly cold day, though only the 31st of August), somewhere about one-third of the way across the sands. Leaving some of our party there, others set off to try and find the kirk. Though we did not find it, we found plenty to make us enjoy the ramble; for anything more varied than the character of these wilds could hardly be imagined. Now you are passing over comparatively level ground, carpeted with wild thyme, violets, berry heather, and ling. Again, you rise over sand-hills with precipitous, cliffy, shell-shaped sides to the south. Now you are down in a deep narrow glen, where some small stream threads its way to the sea, and whose banks are carpeted with a bright green sward. Once more you have to pick your steps, for the ground is spongy and boggy, and here you may pick the Pinguicula, the Drosera, and the Grass of Parnassus (*Parnassia palustris*), and later on the *Trientalis Europea*, most delicate and loveliest of heathy bog plants. But on hill or in hollow, there is always over all the same weird feeling of profound solitude.

Returning to our camp from our southern expedition, two of us started on another due east to see the cliff line. It was a longish walk, at first across a level, rather boggy, expanse. Then we reached a kind of hummocky ground, where the clay came to the surface, with its rich short grass, and where several streamlets united to form a fair rivulet that at the edge leaped over a rock some 50 feet to the strand below, where it trickled on, like a silver thread, till it mingled its sweet water with the brine. It is indeed a lovely spot this Hackley Bay. On either hand the schistose rocks run out in considerable promontories seawards—black below where the rock is exposed, red above where the clay lies upon them, and capped with green where the herbage clothes the clay cliffs.

It is impossible to convey in words the faintest idea of this wonderful buried parish. Once seen it invites, nay, commands, repeated visits, and every visit finds something new to interest, some new source of instruction, some new feature to admire.

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V.—*The Irish or Western Portion of Dr A. Geikie's "Lake Caledonia Basin" of The Lower Old Red Sandstone.* By G. HENRY KINAHAN, M.R.I.A., &c.

(Read 15th December 1881.)

In the Preface to my "Geology of Ireland" (1878), I pointed out that the Lower Old Red Sandstone of Ulster and north-east Connaught belonged to the Silurian formation. Subsequently I brought this subject more prominently forward before the Royal Geological Society of Ireland, and in the pages of the Geological Magazine.

About this time Dr Geikie was preparing his paper "On the Old Red Sandstone of Western Europe," from which we learn that, in reference to the Scotch rocks, the writer had arrived at conclusions very similar to those to which I was led by the corresponding formations in Ireland.

By the aid of a grant from the Royal Irish Academy, I and others were enabled to examine the Curlew and Fintona Mountains more carefully, and an epitome of our Report on those rocks appears in their Proceedings. In this paper I propose to lay before the Society a short description of the rocks in the whole of the western continuation of Dr Geikie's *Caledonia Basin.*

The rocks of this basin, when followed into Ireland, appear at once at the north-east, on the coast of Antrim, and extend in a south-westerly direction across the island; the strata being much thicker and better developed where they disappear to the south-west under the Atlantic, than elsewhere. From the sections exhibited it will be seen that the same principle has been followed as that adopted by Dr Geikie in illustrating the changes in the strata of the Scotch basins.

The Irish Silurians are of two types, viz., the "Lower Old Red Sandstone type," or rocks of red colour, for the most part arenaceous (*Red arenaceous series*), but in some places argillaceous; and the "Silurian type," or green rocks, generally argillaceous (*Green argillaceous series*). In the latter, calcareous beds or limestone often occur, and the fossils are always of marine animal life; while in the former the fossils are principally plants or fucoids. These divisions are purely lithological, not chronological; the rocks of the red types being sometimes above, and sometimes below those of the green types; probably, however, if continuous sections could everywhere be seen, it would be found that the lowest and highest rocks of all belong to the "red types," that is to say, the littoral rocks first de-

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posited and those last deposited are now red, while the deep water accumulations are principally of grey and green colours: these are they which contain beds of limestone. A peculiar feature of these Irish Silurians, to which special attention should be directed, is a zone yielding fossils of Caradoc-Bala types. This peculiarity does not appear to be confined to the strata in the western extension of the "Caledonia Basin," as similar fossils are also found in some of the rocks in Kerry, classed by Jukes as Silurians (western continuation of Geikie's "Welsh Lake Basin"). In reference to these Kerry rocks, however, it should be mentioned, that Griffith classed them with the Cambro-Silurians; while Mr M'Henry, of the Irish Geological Survey, who has lately visited them, inclines to the same opinion.

Silurian Basin principally of the Lower Old Red Sandstone type. In the north-east of Antrim there is an exposure of metamorphic rocks probably of Cambrian age. Lying on these rocks to the northward, in the neighbourhood of Ballycastle, are Carboniferous rocks of the Calp type (Lower Coal Measure of Scotland); while to the south-east, at Cushendun, are conglomerates and sandstones, which are possibly the littoral beds of the north margin of the Silurian basin. Westward and southward the continuation of these rocks is obscured by the newer Cainozoic rocks; while still further westward they must be heaved southward by the faults of the Lough Neagh Valley. West of the Lough Neagh Valley, to the north-west of Moneymore, in the county of Londonderry, there are red arenaceous rocks of uncertain age; these may possibly be an outlying portion belonging to this basin. Farther southward, however, in the counties of Tyrone and Fermanagh, the undoubted Lower Old Red Sandstones appear from under the Carboniferous rocks in the tract which may be called the *Fintona district*, extending from Pomeroy westward to the valley of Lough Erne. These rocks, to the north, lie on metamorphic rocks, probably of Cambrian age; and to the east, at Pomeroy, and south-west, at Lisbellaw, on rocks which, from their fossils, should be classed as Cambro-Silurians.

Further westward the rocks of the basin are heaved southward by the faults of the Lough Erne and nearly parallel valleys, and next appear from beneath the Carboniferous rocks a little south-east of Lough Allen, in the neighbourhood of Drumshambo, County Leitrim.

The Drumshambo Silurians are cut off on their western side by a fault which brings down the Carboniferous rocks against them; but they appear again almost immediately, and form a ridge of high ground (Counties Roscommon, Sligo, and North-East Mayo) to and beyond Ballaghaderreen (*Curlew Mountain district*). The rocks, however, are more or less shifted by

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faults; such as those on the lines of which are situated Loughs Key and Gara. In this tract, as far west as Ballaghaderreen, the basal rocks are not exposed, but to the westward of this, and southward of Charlestown, they appear lying on metamorphic rocks of uncertain age; because, as shown in a paper read by me before the Royal Irish Academy, they may be either Cambrians or Cambro-Silurians, though probably the latter.*

Farther westward the rocks of the basin appear to have been denuded away, as they do not occur again until we reach the Croaghmoyle district, near the head of Clew Bay, in Mayo, where we find littoral rocks lying on apparently metamorphosed Cambro-Silurians. From this, apparently, the Silurian rocks continue out westward along Clew Bay to Clare Island, under the Carboniferous rocks, as they are to be seen at Beltra, Curraun, Clare Island, and Louisburgh.

Further southward, from Lough Mask to the Atlantic (Lough Corrib, Toormakeady, Formnamore, Mweelrea, and Culfin districts), is a detached, nearly parallel, portion of the basin. This detached portion, although it was evidently deposited in a distinct trough from that in which the rocks to the north accumulated, was probably a portion of the main basin, which is now disconnected by denudation, as the Croaghmoyle rocks are so similar to those of Toormakeady. The rocks, however, in the south, now detached, portion are peculiar, inasmuch as they suddenly and rapidly change their character and increase in thickness as they are followed westward. To the westward, between them and the rocks of Clew Bay, there appears to have been a deep trough, in which rocks of a type different from both were deposited.

After this general description, the following details of the rocks may be given, beginning with those of the County Antrim.

The Cushendun rocks are conglomerates, or conglomeritic, and seem to have been deposited on the margin of the basin. Very little more can be said about them, as they are so sparingly exposed.

The rocks north-west of Moneymore, County Londonderry, are pebbly red sandstones, which seem to be connected with the Lower Old Red Sandstone of the Fintona district by small outlying patches. Some of these small patches do not appear on the published maps.

The rocks of the Fintona district are, on the eastern side,

*Griffith, Jukes, and the other older observers mapped these rocks as old metamorphic; while in the new map they are classed with the overlying unmetamorphosed Silurian. This latter classification is undoubtedly incorrect, as they were metamorphosed, upturned, and extensively denuded prior to the deposition of the Silurians upon them.

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nearly all of a red colour, and arenaceous, having in them, at about 1800 feet above their base, interstratified eurites and tuffs. But near Six Mile Cross there appear to be at their base bedded eurites and limestones, over which are red conglomeritic rocks, which are succeeded by green rocks with subordinate limestone; and over them apparently there are other red rocks. This section is very similar to that near Ballaghaderreen, to be mentioned presently, except that in the green rocks and limestones of the latter fossils have been found. It was from near Six Mile Cross that Griffith was sent the fossils, the age of which he could not decide on, and, curiously enough, I am now in a similar predicament. I have been sent fossils from this place by Mr Thomas Plunkett, M.R.I.A., of Enniskillen, which occur in a boulder of a green argillaceous rock very like many of the rocks *in situ* in the immediate neighbourhood, but also very like some of the Pomeroy rocks 6 miles to the eastward. The principal fossil, *Leptæna serica*, is a Caradoc-Bala form, and very common near Pomeroy, but, at the same time, it is the most common fossil in the Toormakeady Silurians, and also in the Mweelrea Silurians; still it is safer to regard the block as a boulder from the Pomeroy Cambro-Silurians until fossils are found in the rocks *in situ* of the Six Mile Cross section.

Towards the west of this area the rocks are almost entirely red and arenaceous, a peculiarity being the inlying bits of shale; these we shall have to refer to again. In the south-west of this area, at Lisbellaw, there is a remarkable sudden local accumulation of massive conglomerates, the inlying fragments being important, as they are from "baked rocks" (hornstone principally), which occur nowhere nearer than the hills of Leitrim (Manor Hamilton). That these conglomerates are only a local mass is proved by their being absent in the section to the north-east, at the north-east end of Lough Eyes, and to the north-west, in the railway cutting. As hereabouts there are whinstones protruding into the Cambro-Silurians, it may be suggested that the fragments were derived from a mass of baked Cambro-Silurian in the vicinity, which is now covered up by the Carboniferous rocks.

At the Drumshambo exposure, which is very small and unsatisfactory, there are rocks of both the red and the green types; the exposure apparently showing the rocks just above and below the junction of the two kinds.

In the eastern portion of the Curlew mountain range there are only exposures of the upper red beds capped in places by outlying patches of tuff; in the low ground to the west, however, between Ballaghaderreen and Charlestown, lower beds make their appearance. The section here is most instructive:—

1. Metamorphic Cambro-Silurians or Cambrians.

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2. Unconformability.	
3. Red and purplish conglomerates, sandstones, and sandy shales, . . .	1,500 feet
4. Green conglomeritic sandstones and shales, with their impure fossiliferous limestones, and a few red shales, .	about 4,000 feet
5. Purplish, red, and greenish conglomeritic sandstones and sandy shales, . .	about 5,000 feet
6. Eurites, tuffs, and limestone (?), . .	over 200 feet
	10,700 feet

The rocks in groups 4 and 5 are very similar, except as to their colour, and that in No. 4 there are some fine argillaceous rocks and impure limestones. The arenaceous rocks in the three groups, 3, 4, and 5, are made up of pieces of the underlying metamorphic rocks; a most important consideration, as recently the latter have been classed as one group with the rocks of No. 4. As before pointed out, this section is very similar to that near Six Mile Cross, in the Fintona district, having red rocks above and below the green. A little above the base of group 4, in the Cashelduff stream, there are, in impure limestones, fossils, principally of Upper Llandovery types, although two or three are of Caradoc-Bala types; but to the eastward, in Griffith's fossil locality, at the mearing of Glenmullynamaher and Uggool, in a very similar limestone, they are principally of Wenlock types; although in shales below and above them, in Glenmullynamaher, to the north, and Cloonnamna, to the south, the fossils are of Upper Llandovery species. Here therefore, as elsewhere in Ireland, there is a mixing up of fossils which in Wales are characteristic of distinct groups of rock.

The rocks in groups 3 and 5 are lithologically similar, and could not be separated if No. 4 had not intervened. Furthermore, the rocks of No. 4 are very similar in composition to those above and below them, the marked difference being as to the colours and the fact that those of the light colours alone carry fossils. The coarse sandstones in each of the three groups are made up of the same detritus, and contain similar thin shale inliers; in fact, it would seem as if No. 4 ought not to be recognised as a separate group, but as an accidental inlier in the rocks of the Red arenaceous series.

No satisfactory section of the rocks of group 6 is exposed, although enough of them is seen to show that they lie in the trough of a synelinal curve; also that subordinate limestones are associated with them. In the country west of Lough Key a thin impure limestone was observed *in situ;* while in the district north-west of Ballaghaderreen fragments of limestones like those of Eskerboy, County Tyrone, are frequent.

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The sections in the Curlew mountain district are so far instructive, that from them we learn that the rocks of the "Lower Old Red Sandstone type" (*Red arenaceous series*) were accumulating at the margin of the Silurian sea, while more argillaceous and calcareous rocks were being deposited in deeper or quieter waters in which lived and died mollusca characteristic of the Welsh Silurian sea; also that subsequently these latter rocks were covered by accumulations of the "Red arenaceous series."

In two places in this area, to the north of Doon, on the west margin of Lough Key, and at Moygara, to the north-west of Lough Gara, tracks (doubtless Crustacean) similar to those found in the Glengariff Grits, Valencia, County Kerry, were observed.

Westward of the area last described there must have been a hill of old rocks in the Silurian sea, because farther westward at Croaghmoyle the rocks are littoral, being massive conglomerates or breccia, except in one locality to the westward, where apparently under the conglomerates is a considerable thickness of red sandstone and sandy shales; there are also in places limestones at the base.

Still further westward in the vicinity of Clew Bay, near Molrany, in Curraun, in Clare Island, and at Louisburgh, there are also conglomerates and red sandstones; but associated with them are greater or less thicknesses of red shales and slates. Northward of Louisburgh the argillaceous rocks are of considerable thickness; while in the hill to the westward are interstratifications of shales and sandstones, with subordinate conglomerates. The Louisburgh beds are perhaps the newest accumulations in the whole of this portion of the basin; they approach more nearly in lithological character to those of the Glengariff Grits than any of the others.

The relations between the rocks just described and those in the detached portion, or nearly parallel trough, extending from Loughs Mask and Corrib to the Atlantic, at the Culfin, have next to be mentioned. To the west of the north portion of Lough Mask, that is, in the Slieve Partry or Toormakeady district, there are rocks nearly identical with those of Croaghmoyle, except that in limestones at the base of the group are fossils of Caradoc-Bala types, one very characteristic, *Leptœna serica*, being the fossil mentioned as found in a loose block near Six Mile Cross, County Tyrone. These rocks westward in the Formnamore Mountains rapidly lose their character and change into green sandstones, grits and shales; while still further west, in the Mweelrea Mountains, they are partly of the Toormakeady type and partly of the Formnamore type; while a little above their base is a fossiliferous zone, carrying fossils similar to those of the Toormakeady rocks (Caradoc-Bala types).

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North of the Mweelrea Mountains, and south of the Louisburgh beds, from which they are separated by a fault with a downthrow to the northward, is a small independent trough of Silurian rocks. These appear to have belonged to the green argillaceous series, but now are all metamorphosed, except a small area at Creggaunbaun (to the south-west), where the rocks are very fossiliferous, the fossils being of Wenlock and Lower Llandovery forms, similar to those at Kilbride (Lough Mask).

Returning again to Lough Mask. The rocks of the Toormakeady, the Formnamore, and Mweelrea types are bounded on the south by a fault, with a downthrow to the southward extending from Lough Mask to the Little Killary, on the Atlantic, and south of this fault the rocks are of new types. To the eastward at Kilbride (Lough Mask), and adjoining Lough Corrib, the rocks are similar to those of Creggaunbaun, and contain similar fossils. Farther westward, as we approach the Maum Valley, we have red rocks above and below; the first (*Salrock slates*) containing, as their characteristic fossil, *Lingula Symondsii*, pronounced by Davidson to be an Upper Llandovery form. In the lower red beds no fossils have been found; while in the intermediate green and grey beds all the fossils are of Lower Llandovery and Wenlock forms, the first predominating. Still further west there are, below, the Gowlaun group; in the centre, the Lough Muck group; and above, the Salrock slates. The first to the westward, or adjoining the sea, is nearly altogether slates, which change eastward first into green grits, and near Lough Fee and the Blackwater into red conglomerates with subordinate shales. The fossils in these are all of Lower Llandovery forms. In the rocks of the Lough Muck series the fossils are of Lower Llandovery and Wenlock forms, except on one zone, where they are of Caradoc-Bala types. The fossils of the Salrock slates have already been mentioned. These rocks are lithologically similar to the slates at Louisburgh, but in the latter no distinct fossils have been found.

This portion of the basin between Loughs Mask and Corrib, on the east, and the Atlantic, on the west, is very instructive, on account of the rapid changes both lithologically and as to the fossils, not only from east to west, but also in places across that direction; also in the changes between its rocks and those in the main basin to the north. To the eastward, the Toormakeady rocks and those of Croaghmoyle are identical; but to the westward there are great changes, one set of rocks being found south of the Killary, another in Mweelrea, a third in Creggaunbaun, and a fourth at Louisburgh; as shown in the accompanying section.

In connection with the sedimentary rocks of this basin there are eruptive rocks, principally purplish and greenish eurites, or

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basic felstones, similar to the rocks found in the Scottish portion of the "Lake Caledonia basin."

These eurites are best developed towards the west, where, in the south trough, they occur in a massive bed or beds at the junction of the Gowlaun and Lough Muck groups; that is, about 2700 feet above the base of the Silurians. These can be traced eastward as far as the Maum Valley. There is also a higher bed in the Salrock slates. At or near the base of the rocks of the Mweelrea, Formnamore, and Toormakeady district there are together from one to seven beds there in places in mass, as in the Formnamore district between Loughs Nafooey and Mask. These rocks are continuous from the Atlantic to Lough Mask *under the rocks of the different types*, and probably are on the same geological horizon as the eurites between the Gowlaun and Lough Muck groups.

In the Silurians round Clew Bay, as also those near Beltra and Croaghmoyle, there are not any eurites recorded; but at the base of the latter there are limestones similar to those associated with the Toormakeady eurites.

In the westward part of the Curlew Mountain district, near Ballaghaderreen, there are elvans and other root rocks; while east of Lough Gara the highest rocks exposed are thick massive tuffs or tuffose rocks, each mass being made up of a series of beds from 1 inch to 4 or 5 feet thick. This would seem to indicate that the flows of eurite graduated eastward into beds of tuff and tuffose rocks.

In the Fintona district there is at, or outside, the northern limits of the Silurian rocks an exposure of the granite or elvan roots of the eurites. The eurites seem to occur on two horizons. Those on the upper are very similar to those of the Toormakeady district, being made up of beds of eurite, tuff, and limestone; except for one peculiarity, which is that all the bedded portions of the eurite are affected by a structure that splits them up into slates and flags.

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V.—*The Glaciers of Lower Strathnairn.* By DAVID CAMERON, Daviot.

(Read 15th December 1881.)

Traces of a Silurian and Old Red Glaciation.—These traces are found in a detached bed of old red conglomerate in the Nairn, above Daviot Bridge, and referred to in "Trans. Geol. Soc. Edin.," vol. iv., part i., p. 98. The base of the Old Red is only a few yards in thickness. This conglomerate is composed chiefly of three kinds of rock; the largest and most common being a hard crystalline gneiss of dark colour, dark schist, and red porphyry, cemented together by coarse clay of dark brown colour, very like the gneiss upon which this Old Red formation rests. This clay is full of small stones of the same nature as the large ones, with the addition of a few small fragments of red granite. There are no traces of gravel in the mass. None of the stones are water-worn or rounded, but are mostly angular. The largest ones (gneiss) occur very often, and measure from 2 to 3 feet diameter. They are, without exception, arranged with their longest axes from south-west to north-east, parallel to the line of the valley. It will also be observed in the conglomerate bed that, when the smaller stones, particularly the long and thin ones, come in contact with the larger ones, they are slightly deflected from their axial course, and lie close to the south-west or adjacent side of their big neighbours; another proof that the glacial current was to the north-east. This was the course of the most recent glacier that passed down this valley. Hence we may infer that the valley was formed before the occurrence of this early glaciation with which the Silurian period ended and the Old Red Sandstone commenced.

Denudation of the Old Red Sandstone.—It will be observed that the valleys of the Ness, the Nairn, the Findhorn, and the Spey run generally parallel to one another in a north-easterly direction, and an examination of the *roches moutonnées*, and the striation of these valleys and their intervening hills, shows that their general glaciation was towards the north-east. It will also be observed that the lower parts of these valleys are covered with Old Red Sandstone. Detached portions of Old Red conglomerate occur in several places far inland, the most notable instance being at Tomintoul. Transported blocks of conglomerate are plentiful beyond the Old Red line. They occur around Loch Moy, and 6 miles higher on the Findhorn. There are proofs to show that the glacial current was comparatively strong in the

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upland parts of the valleys. Hence the absence, through denudation, of the Old Red in the higher reaches of these rivers, and its presence along the south shores of the Moray Firth. The Old Red in the bottom of the Nairn valley is a rough conglomerate, but gradually gets finer as it ascends the slopes towards Daviot Mains on the left side, or towards Daltullich on the right. Thus we have a curved crust of Old Red crossing the valley between these two places, rough conglomerate in the bottom, and fine Old Red up the opposite slopes, with the same dip, about 25° north, corresponding with the depression of the Moray Firth. A little lower down, where we enter a broad lowland district, we have the finest sandstone in the bed of the river. This rule is also applicable to the boulder clay. It is coarse in the upper regions, but it is exceedingly fine on the low grounds, especially at Culloden Tile Works. These respective conditions in the Old Red and the boulder clay are evidently due to current ice action, which, from the nature of the ground, would be strongest in the narrow upland valleys and passes.

Transported Blocks.—Both on the slopes and in the valley we may observe huge blocks of gneiss as large as a highland cottage, sometimes perched in peculiar positions, as in the large block below Daltullich. We have also conglomerate blocks and varieties of granite from Stratherrick sometimes intermixed with a few from remote localities. Some are perched on striated rocks, yielding the testimony of the block and of its striated platform as to the direction of the local glaciation, which to some extent followed the windings of the valley. A thin line of conglomerate blocks winds along the south side of the valley from Mid-Lairgs to Mid-Craggie, and from thence round the north shoulder of Meall-Mor of Daltullich, where the blocks occur in very great profusion. At the latter point the Old Red is *in situ* near these blocks, and they are evidently within a short distance of their native sites. Another line of conglomerate blocks winds along the north side of the valley from Faillie by the line of junction of the Old Red and the gneiss, and resting chiefly on the gneiss. The two lines of transported blocks are, as a rule, of equal elevation, about 800 feet.

Above Craggie Farm, at fully 700 feet, we have a cluster of large gneiss blocks, evidently transported from some hill to the south-west, probably by an iceberg at a subsequent period. Another remarkable group of gneiss blocks occur at Dalvourn, 4 miles up the valley, chiefly on a sandy plateau, which evidently contains no blocks (635 feet). They were apparently carried there by floating ice.

The Strathnairn glacier, as shown by the rock striations at Dalvourn and Craggie Mill, moved to the north-east by north (magnetic) with slight variations, evidently caused by the windings of the valley.

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Sand Hills.—The sand hills flank the sides of the valley from Faillie seawards. On the north side they are roughly terraced, about 100 feet high, and cut up at short intervals by the side currents. The sand, as shown by its numerous sections, contains no blocks. It evidently marks a submergence accompanied by a milder climate and an iceless sea, in which the higher mountains formed an archipelago among whose islands the currents circulated. But the cold returned, and icebergs transported blocks from one part to another.* These sand hills are thickly strewed with blocks. Here the main current would carry the floating ice north-east. Hugh blocks of gneiss were floated eastwards from Doune Daviot, and stranded upon the yielding sand into which they have sunk a few feet. Numerous blocks of conglomerate were also floated and deposited. Several blocks of Stratherrick granite occur on the higher parts of these hummocks. They are very numerous in this district, and occur on Ben Beurlaich at 1550 feet.

Local Glaciers and their Results.—When the land rose to its former level, and the last glaciers descended from their upland valleys, and, along with the detritus left by the sea, filled up the narrow passes, temporary lakes were formed sometimes in their rear, and also on their flank where they crossed a lower valley. Such was evidently the case here at Craggie, when the last glacier from Strathdearn descended to the Nairn, ploughing its way through an older moraine, containing great fragments of red granite, found *in situ* to the rear. Its smallness is apparent from the facility with which it adapted itself to the gentle windings of the Craggie valley, combined with the evidences of an older and greater glacier, whose line it crossed here almost at right angles. The valley of the Nairn is flanked, particularly at Scatraig, by very regular terraces or lake margins, about 15 feet high, showing the maximum height of a lake evidently caused by this ice barrier. A smaller lake was formed at Dunlichity solely by detritus.

The Findhorn and its Lake.—This is by no means a new idea.† It is equally evident that the passage of the Findhorn was about the same time blocked by ice and *detritus* at the pass of Pollochaig, and that a lake was formed, of which Loch Moy and Lochan Chaoruinn are the remains. The requisite barrier at this latter lakelet was possibly formed by the rear of this last glacier which descended the Craggie valley. That there was a barrier here is strikingly shown by the great quantity of sand deposited upon the ridge (922 feet) at Lochan Chaoruinn, showing by its fine and almost horizontal stratification that it was deposited under still water. This ridge is covered by 40 or 50

* See "Geology of Cumberland," by the Rev. J. Clifton-Ward.
† See "Morayshire Floods," by Sir Thomas Dick Lauder.

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feet of sand and by 5 or 6 feet of peat. The maximum level of this lake may be tested by its terraces or margins, 884 feet,* near the confluence of the Funtack Burn and the Findhorn.

It will thus be apparent that the Findhorn might flow over the ridge at Lochan Chaoruinn on to the Nairn before the sand was deposited upon this ridge (922 feet). But we must assume that the levels, at least relatively, are much the same now as they were then, apart from this recent formation on the ridge (922 feet). We have no evidence that this river was at any time completely diverted from its original channel.

Gorge.—The lacustrine waters of Strathnairn escaped through the gorge below Craggie. The denudation in a narrow valley or pass would be great, owing to the mechanical pressure of the ice. The gneiss strata of the gorge are almost vertical.

VI.—*Note on Fossiliferous Strata, Lower Strathnairn.* By DAVID CAMERON, Daviot.

(Read 15th December 1881.)

In one of my visits last summer (1881) to Castletown Burn, I was fortunate enough to find the fossiliferous strata, herein referred to, in this burn a few yards below the bridge on the main road. The rock in which the fossils occur is situated on the left side of the burn, and 560 ft. above sea-level. In breaking off a few fragments I found the specimens, which I forwarded to Edinburgh. These were identified *Coccosteus* sp., *Depterus* sp., and *Osteolepis* sp., characteristic Old Red fossils.

* See O. S. Map, large scale.

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VII.—*Analysis of Laterite from Huranbee, Pegu.* By R. ROMANIS, D.Sc., Rangoon.

(Read 19th January 1882.)

Laterite is a rock found in tropical countries. In appearance it resembles some kinds of weathered trap; thus among the detritus of the amygdaloid porphery of Arthur's Seat fragments may be found exactly resembling laterite. Lyell, in his Manual, pronounces laterite to be a decomposed trap. My examination of a specimen of laterite from Huranbee, about 20 miles from Rangoon, shows that it is of aqueous origin.

This laterite is brought into Rangoon as road metal. It is a bright red friable rock, full of cavities, the cause of which is a puzzle to geologists. It hardens when exposed to the air, hence its value in building and road-making. Chemical analysis shows that it is composed of oxide of iron, alumina, silicic acid, and quartz sand. When the sand is examined under the microscope it is seen to be water worn.

The following are the results of an analysis:—

Oxide of iron, . . .	36·28
Alumina, . . .	9·72
Sand, ...	31·44
Silica (soluble), . .	13·27
Water, ...	8·83
	99·54

I shall endeavour to procure specimens of laterite from the mountains, which is supposed to be of different origin from that of the plains.

The process of the formation of laterite may be observed in any section of a sandy soil near Rangoon.

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VIII.—*Analyses of Coals from New Zealand and Labuan.* By W. Ivison Macadam, F.C.S., F.I.C., Lecturer on Chemistry and Analytical Chemist, Edinburgh, *Honorary Secretary to the Society.*

(Read 19th January 1882.)

1. Analyses of Coal.

	Labuan Coal.	New Zealand. No. 1.	New Zealand. No. 2.	New Zealand. No. 3.
* Volatile Matter,	27·321	10·683	45·743	35·243
** Fixed Carbon,	70·924	69·755	49·573	62·115
** Ash,	1·755	19·562	4·684	2·642
	100·000	100·000	100·000	100·000
* Moisture,	6·942	6·162	13·922	4·442
** Coke,	72·679	89·317	54·257	64·757
Sulphur,	0·085	0·282	0·122	0·106
Specific Gravity (Water 1000),	13·314	16·879	13·313	12·926

2. Analyses of Coke.

	Labuan.	New Zealand. No. 1.	New Zealand. No. 2.	New Zealand. No. 3.
*Fixed Carbon,	97·585	78·098	91·358	95·920
Ash,	2·435	21·902	8·642	4·080
	100·000	100·000	100·000	100·000
* Sulphur,	0·021	0·076	0·032	0·014
Character of Coke,	Very slightly coked; hard black.	No caking or other change on heating.	No caking or other change on heating.	Cokes hard, black.
Colour of Ash,	Red.	Gray.	Yellow red.	Gray.

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3. Analyses of Ash.

	Labuan.		New Zealand. No. 1.		New Zealand. No. 2.		New Zealand. No. 3.	
I.—*Soluble in Water.*								
Potassic Oxide, .	0·212		0·014		0·106		0·032	
Sodic ,, .	0·086		0·011		0·064		...	
Calcic ,, .	0·041		0·062		0·055		0·024	
Chlorine, . .	0·022		0·018		0·021		...	
Sulphuric Anhydride,	0·032		0·046		0·041		...	
		0·393		0·151		0·287		0·056
II.—*Soluble in Acids.*								
Cupric Oxide, . .	0·085		...		0·235		0·338	
Ferric ,, . .	75·911		7·274		22·540		9·231	
Aluminic ,, . .	8·121		14·162		20·649		17·888	
Calcic ,, . .	3·703		1·751		18·855		1·861	
Magnesic ,, . .	6·210		0·307		1·931		0·750	
Phosphoric Anhydride,	0·342		0·232		0·567		0·518	
Carbonic, ,,	0·298		1·187		17·667		1·525	
Soluble Silica, .	3·003		1·532		2·626		1·554	
		97·673		26·445		85·070		33·665
III.—*Insoluble in Acids.*								
Ferric Oxide, . .	...		3·728		1·421		7·041	
Aluminic ,, . .	...		10·389		0·112		4·238	
Calcic ,, . .	...		...		0·169		...	
Silica, . . .	...		59·018		12·685		54·886	
		1·802		73·135		14·387		66·165
Loss and undetermined,		0·132		0·269		0·256		0·114
		100·000		100·000		100·000		100·000

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IX.—*Remarks upon the Geological Formations of New Zealand.* By J. COUTTS CRAWFORD, Esq. of Overtoun, late Resident Magistrate and Sheriff of Wellington, New Zealand, *Foreign Corresponding Fellow.*

(Read 16th March 1882.)

In page 506 of the "Proceedings of the Royal Society of Edinburgh," it is thus written :—

"It is now known that, with scarcely an exception, all oceanic islands other than coral atolls are of volcanic origin."

To this is appended the following note:—"New Zealand, New Caledonia, and the Seychelles have primitive rocks, if these can be regarded as oceanic islands."

I propose to offer a few remarks to show that New Zealand does not come under the above definition of an oceanic island or islands any more, almost, than that the British Islands should be included in the same category.

I say *almost*, because there is no doubt that Great Britain and Ireland stand on the European plateau, and that New Zealand is separated by a deep sea from Australia, and by a deep sea and a great distance from South America; but, on the other hand, there is reason for supposing that the land boundaries of New Zealand were at one time much more extensive than they are now, and probably included Norfolk Island, the Chatham group, Campbell Island, and the Auckland Islands, these islands having a similar *flora*, and in some respects a *fauna* also.

I am not sufficiently acquainted with the soundings to say how far the New Zealand land surface extended at one time into the tropics, but that it did so is probable from the character of the vegetation, from finding tree ferns and palms reaching as far as Lat. 47°, and from the lianas in the forests, which give them a tropical appearance.

Igneous Rocks.

The idea is prevalent that New Zealand is essentially a volcanic country, whereas it may be doubted whether the area covered by igneous rocks exceeds that occupied by the same rocks in the British Islands, taking into consideration those of the lowlands of Scotland, of the Western Highlands, and of the north of Ireland.

Australia is usually looked upon as a country of sedimentary rocks, but it appears to me that the area covered by traps,

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basalts, quartz porphyries, &c., in the elevated country from Bass Strait to Cape York exceeds proportionally that occupied by igneous rocks in New Zealand.

If we include granite as an igneous rock, then the proportion both in the British Islands and in Australia is largely increased.

Chief Area of Volcanic Eruptions in New Zealand.

North Island.—If we draw an east and west line from Mount Egmont, Taranaki, to Ruapehu, the highest mountain in the centre of the island, nearly 10,000 feet high, we shall find that all the volcanic rocks lie to the north of that line. There may be deposits of water-borne pumice and of ash to the south, but there are no volcanic vents.

South Island.—There are old volcanic outbursts, probably submarine, at Banks' Peninsula, Timaru, Waikowaite, Dunedin, and also skirting the junction of the Canterbury plain with the mountains, but the area occupied by these rocks is comparatively small. Banks' Peninsula is entirely volcanic.

Stewart's Island is granitic.

Nearly the whole Geological Scale represented in New Zealand.

Almost the whole geological series is found in New Zealand, as follows, in an ascending scale :—

	Granite.
	Gneiss.
Palæozoic.	Lower and Upper Silurian. Devonian. Carboniferous. Unfortunately without coal.
Mesozoic.	Trias. Lias. Rich in Saurians. Cretaceous. Containing thick seams of coal including Green sand.
Tertiary.	Eocene. Meiocene. Pleiocene.
	Post Pleiocene.
	Recent.

Therefore it may be seen that New Zealand geological formations are almost, if not quite, as complete as are those of the British Islands.

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The Silurian has given *Graptolites* and some other characteristic fossils—the Devonian *Monotis*, &c.; the carboniferous, I think, *Spirifer* and *Glossopteris*. As we ascend in the scale, I fancy the fossils become more changed in their types from European representatives; the lias, for instance, containing Saurians of new species, and cretaceous and tertiary mollusks being of local character; but I am away from books and authorities, and therefore say little on the subject.

The area of palæozoic rocks is very large in the South Island. In the North Island they form large meridional, but narrow ranges of mountains, and are covered up and hidden by tertiary rocks over a great extent of country.

In the centre of the North Island much country is covered by thick deposits of pumice, the ejection of which by the volcanoes must have been on an enormous scale. Hundreds of square miles are now covered by this deposit. How it was distributed I have endeavoured to show in the pages of the "Transactions of the New Zealand Institute," but it would be too long an affair to go into now.

Volcanoes.

Although the New Zealand craters are on a small scale as compared with those of the Hawaiian Archipelago and other oceanic islands, yet some of them are really magnificent. Mount Egmont, probably extinct, is over 8000 feet high, and forms a cone of extreme beauty of outline, sloping like Vesuvius into fertile plains. The great central group, commonly called Tongariro, but consisting of Ruapehu on the south, Tongariro on the north, and Ngauruhoe rising on the south-western slope of Tongariro, form a most unique and picturesque feature in the middle of the island. Roto Aira lies at the northern foot of Tongariro, and Lake Taupo a few miles further north.

Ruapehu is nearly 10,000 feet high, is a very old volcano with its softer parts washed away, and therefore exposes sharp peaks of the harder rocks. Both it and Tongariro have lakes in their craters.

Ngauruhoe is the present cone of eruption, a handsome cone 6200 feet high; it always smokes, and sometimes throws out ashes.

Numerous smaller cones, some of considerable size, are dotted about all the country to the northward; while White Island, in the Bay of Plenty, is always sending up steam and smoke, and depositing sulphur.

The hot springs and geysers of Rotomahana, Rotorua, Tokano, &c., have been so often described that I need only say that they appear to be the finest of the kind in any part of the world, excepting possibly those of the Yellowstone River in the

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United States. I am not competent to say which would carry off the palm, but the New Zealand hot springs are certainly the most accessible, being within forty miles of the sea.

Recent Deposits.

The recent deposits of New Zealand are particularly interesting from the large numbers of moa skeletons which are found in them, and from the evidence which they afford of a former great extension of glaciers. As the existent glaciers of New Zealand are said to exceed in magnitude those of the European Alps, they must have been formerly of enormous extent. The snow rivers of the South Island give a good idea of the magnitude of the present glaciers and névés, the Clutha being said to carry as much water to the sea as the Nile; while the Waitaki, the Rangitata, the Rakaia, the Waimakariri, &c., discharge enormous quantities of snow-water.

New Caledonia, Norfolk Island, Howe's Island.

I am not personally acquainted with New Caledonia, but from verbal description I suppose its leading feature to be a long ridge of palæozoic rocks, possibly Devonian or Silurian. I have never heard of igneous rocks being found there. It contains mines of nickel, which tends to confirm the above supposition; and I believe small quantities of gold have been found.

Norfolk Island I suppose to be formed of sedimentary rocks, I cannot say of what age, and to be non-volcanic; but I have never seen it, and speak from hearsay only.

I passed Lord Howe's Island some forty-one years ago. The impression left on my mind is that it is composed of some hard metamorphic or igneous rock, at all events not modern volcanic. It is a high, steep rock. From its form I should say it was not granitic, but it may be porphyritic.

New Caledonia is connected with Australia in its *fauna* and *flora*, Norfolk Island with New Zealand.

There is nothing new in what is now stated; but as I have observed that many people look upon the New Zealand Islands as being essentially volcanic, I think a fresh contradiction of this idea may be desirable.

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X.—*Second Additional Note on the North-East Coast of Norfolk, by* Wm. R. M'Diarmid.

(Read 16th March 1882.)

In the spring of 1879 I had the honour of reading, at a meeting of this Society, some notes on the North-East Coast of Norfolk, and in January 1880 an additional note on the same subject. These notes referred chiefly to the amount of denudation of the cliffs on the north-east coast of this county, which extend for a distance of twenty miles.

In October last I paid a short visit to Cromer, which stands nearly in the centre of this line of cliffy coast, and learned and saw that another large amount of destruction of cliff had taken place, owing, as I believe, to the unusually heavy rains of the preceding spring and autumn. In fact, in walking along the summit of the cliffs from Cromer to Sidestrand, a distance of 6 miles, evidence of fresh landslip was apparent at every few yards. The principal fall had occurred at Foulness Head, near which Foulness Lighthouse stands: here upwards of an acre of land had fallen at once, and a large portion of the *debris* was still lying at the foot of the cliff, on which the waters of the sea had then exercised little wasting effect. This fall has perceptibly diminished the distance betwixt the lighthouse and the sea. The present is the second lighthouse which has been erected at this point. It was built in 1832, in consequence of the insecurity of its predecessor owing to landslips, and was erected considerably further inland than the original building, which ultimately fell into the sea in the spring of 1867, along with another great landslip. To all appearance the present substantial lighthouse will, in the course of time, share the same fate, unless the cliffs now crumbling away from the effects of rainfall are protected, as is the case at Cromer, by means of a sea-wall, the erection of which would perhaps be more expensive than that of a third lighthouse.

The cliffs in the vicinity of the fishing village of Overstrand had suffered severely, and obviously, from the fresh marks, in autumn; but the chief landslip there had occurred in spring, and so suddenly that a ploughman and pair of horses, which at the time were at work on the soil near the summit of the cliff, made a narrow escape from being precipitated on the beach below. The horses, upon feeling the tremor of the ground beneath their feet, shied and plunged, but fortunately in an inland direction, and they and their driver were saved. Betwixt Overstrand village and the lonely churchyard of Sidestrand

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there were frequent evidences of landslips, the principal having occurred at Sidestrand Head, which has diminished the distance betwixt the churchyard and the sea to one small field. So narrow was the intervening space remaining that it had been found necessary to take down the parish church of Sidestrand, nothing having been left except the tower, to serve as a beacon as long as it stands, and a new parish church was in the process of erection about half-a-mile westward and inland.

Next day I examined the coast betwixt Cromer and Weybourne, a distance of 7 miles. Along this line of cliff the chief destruction had been done at the fishing village of lower Sheringham, where nearly all the ground in front of the coastguard station had fallen, and here and at other points of the village the construction of sea-walls showed what was required for the security of buildings.

According to the views taken by Sir Charles Lyell, these long lines of cliff, composed almost entirely of sand, clay, gravel, and loam, are the result of glacial drift, while the cliffs rest upon a floor of chalk. A small portion of this floor is visible at the foot of a cliff 2 miles south of Overstrand, while betwixt Cromer and Weybourne numerous sections of this chalk are seen, white in hue and hard in texture. At one point, and only one, is the chalk visible in the cliff itself, and raised above the level of the sea: this occurs about 3 miles north-west of Cromer, and is massive in extent, but softer in texture than the chalk below which here forms the bed of the German Ocean. This mass of chalk is described by Sir Charles Lyell in his "Antiquity of Man," p. 264, and an engraved sketch accompanies the letterpress. Sir Charles says:—

"To the north of Cromer fragments of chalk and crushed masses of the same rock many yards in diameter often occur. Several striking examples may be seen both in the sea-cliffs and inland in pits worked in the drift. I saw one conspicuous example in 1829 in the sea-cliff west of Sheringham, where an enormous pinnacle of chalk, between 70 and 80 feet high, was to be seen flanked on both sides by vertical layers of loam, clay, and gravel. The mass, though much altered, was still visible in 1839, but when I visited the spot in 1869 it had disappeared. This chalky fragment is only one of many detached masses which have been included in the drift, and forced along with it into their present position. Below the drift the level surface of the chalk *in situ* may be traced for miles along the coast where it has escaped the violent movements to which the superincumbent strata have been exposed."

There are now only a few fragments of chalk with flints embedded lying along the beach, but at the point mentioned by Sir Charles the great mass forming a portion of the cliff as de-

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scribed and drawn by him is now perfectly visible and recognisable. The only change I could detect is that the chalk stands out more distinctly now from the adjacent drift than it did when pictured, probably owing to the wasting of the surrounding sand. How this mass of chalk should have been visible in 1829 and 1839, have disappeared in 1869, and reappeared may afford matter for speculation. It seems to have been visible in 1875, as it is mentioned in "Murray's Hand-Book of Norfolk" of that date, and I certainly saw it in 1878, on my first visit to this coast. Perhaps in the interval between Sir Charles' last visits the chalk had been temporarily covered by an avalanche of sand from the summit of the cliff, such as I described as having witnessed on this coast in my last note on the subject.

The beach or foot of the cliff south of Cromer consists almost entirely of sand and clay. North-west of Cromer there is much more variety. In addition to the chalk already mentioned, there is a quantity of shingle, which increases in amount in the direction of Weybourne. At the coast-guard station there the cliffs, which had for miles been gradually becoming lower, suddenly disappear, and are replaced by an enormous bank of shingle, which runs westward along the shore for upwards of 4 miles. In shape it resembles a railway embankment, and its depth seaward is such that vessels of large burden can lie close to. Some idea of the mass may be formed from the fact that at the head of the valley of Weybourne, which is some 2 miles long, a stream takes its rise from a land spring of considerable volume, and flows down to the sea, which it cannot enter—that is barred by the Weybourne bank—and the checked stream forms the largest sheet of fresh water which I met with in North Norfolk.

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XI.—*The Glacial Phenomena of Athole.* By DAVID CAMERON, Daviot.

(Read 16th March 1882).

Introduction.—The glaciation of the basin of the Tay is more difficult to decipher by the striations than that of the Nairn, because, as a rule, the schistose rocks of the former are soft and not so well adapted to withstand the action of the weather. The geologist, besides examining the directions of the striæ, will require to study very minutely the relative position of the transported blocks and the glaciated rock surfaces. In the meantime we refer more particularly to the higher reaches.

The Rocks.—The rocks of Athole are chiefly metamorphic schists of a bluish grey colour. Porphyritic rocks and granite are prevalent on the south flank of the Grampians from Glencoe to Loch Lydoch, and from thence round by the head of Loch Rannoch to Loch Errocht, and from Struan Point to the higher reaches of the Garry and the Tarf. Limestone occurs at Coshieville and White Bridge, and in Strathtummel, Glenerochty, the Vale of Athole at Innervack, Tulloch Hill, Sheirglass, Strathgarry, Urrard, Strathgroy, Lude, and in Glentilt to the east of the Tilt and the Tarf, and at Falar. Beautiful varieties of rock crystals are common on some of the hills, such as Scarsoch, at the head of Glentilt, and Craig Fonvuick, near Killiecrankie. The minerals of Glentilt include marble of different shades of colour, found about 6 miles from Blair, splendid rocks of salite, and various kinds of the most beautiful tremolite at the bridge above the Marble Lodge.

The general glaciation of Athole was, as a rule, to the south-east, as shown by the striæ on Struan Point (1387 feet), Tulloch Hill (1541 feet), and by the fine *roches moutonnées* on the hills to the south of Aberfeldy. Drummond Hill (1500 feet), at Kenmore, is remarkable for its isolated position in the valley of Strathtay. Its north side is clear of blocks, but many blocks are stranded upon the ridge, and they are strewed over the south side. The ridge is, in many places, cut across by deep gorges, all running from about N.N.W. to S.S.E. The strata are sometimes bent in this direction, and blocks are piled up in positions which indicate that the ice movement corresponded to the line of these gorges, which are deepest on the south crest, upon which we would expect the mechanical pressure of the ice to be greatest. This may be seen to the best advantage at that part of the ridge opposite Fortingall.

The Boulder Clay.—The north sides of the mountain ranges of

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Athole, which run more or less to east and west, are comparatively steep and rocky, as they were exposed to the brunt of this ice movement from the north-west, and the rocky debris and clay which were brushed off them were strewed over the opposite sides, which, as a rule, are gently sloped, and present an undulating aspect. Thus the clay is found in the greatest abundance on the south slopes of such ranges. A few of the highest summits, such as Ben Vrackie (2757 feet), Schiehallion (3547 feet), and Ben Lawers (3984), raise their rugged heads high above the limits of the glacier and the clay. Boulder clay of a light yellow colour fills up the troughs of the mountains as high as 1800 feet, as in the hills to the south of Glentilt, Glenmark, Glengirnaig, the south-east slopes of Ben Vrackie and Meall Uaine, and the south-facing slopes of Glenfincastle, Strathtummel, and Strathtay. The grandest sections occur further north on the south flank of the Grampians.

The Transported Blocks.—The same rule applies to the blocks. The south-facing slopes of Glengarry and the Vale of Athole from Clunes to Bruar, of Glenerochty from Blairfettie to Struan, of Strathtummel from Tummel Bridge to Aldcharmaig, of Strathtay from Dull to Logierait, are all profusely strewed with blocks, which in many instances give the hills a grey appearance, as seen from the distance. Some, however, were transported far beyond their native mountains, and stranded on the Old Red Sandstone ridges of the Stormont, as on the Hill of Caputh. The boulders of the Tilt are remarkable for their great size, variety, and beauty, particularly the granites, schists, porphyrites, and marble.

Submergence.—The numerous sand hills containing no blocks which occur in the basin of the Tummel render their testimony as to the submergence of Scotland. As the land continued to sink the cold returned, and huge masses of floating ice were borne about by the circulating currents. The ice carried numerous blocks from the higher mountains whose summits formed the islands of this Arctic sea, and deposited some of them upon the sand hills. The blocks sometimes show the directions of these currents. From Ferragan and its range they seem to have moved south-west, from Birnam Hill north-east by east, from Ben Vrackie and Meall Uaine west by north across the Pass of Killiecrankie, from Cammoch Hill E.N.E. These two currents evidently met above the confluence of the Tummel and the Garry. Here we have a great sand hill with blocks tilted against the sides facing these currents.

Local Glaciers.—When the land rose again to its former level, small glaciers descended from the higher valleys. One descended from the hollow above Auchlany, moved E.N.E. across Glengarry in the direction of Clunes. Another glacier de-

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scended south from the hollow of Ruidh Chail, and crossed the valley below Dalnamine. A third glacier descended from the elevated hollow of Corhulichan, east, into the Pass of Killiecrankie. Its course may be traced in the ravine below Tenandry Church. Huge blocks were piled upon one another; the strata of rocks *in situ* are bent downwards. The descent of these glaciers, combined with the detritus left by the sea, transformed Glengarry, the Vale of Athole, and Strathtummel into temporary lakes, whose margins may be recognised in the strange terraces which flank these valleys. They are quite different both in their nature and origin from the lower terraces along the sides of the river. These ancient lake margins may be seen to the best advantage at the following places:—(In Glengarry.) From Dalnamine to Dalnacardoch, and also on the opposite side. At Drumuan, Urrard, Aldclune, Kingsisland, Balintoul, Bridge of Tilt, and Bruar, and on the opposite side (south) at Struan, Innervack, Strathgarry, and Balrobbie.

(In Strathtummel.) At Tummel Bridge, Foss, and round the sides of Lochtummel. It is evident that in very recent times this lake extended west to Tummel Bridge, and laved the base of the old terrace referred to. Sometimes after very heavy rain the lake covers the low meadows for two miles in this direction, and if it were to rise a few feet higher, it would reach Tummel Bridge. This overflow is caused by a rocky barrier at the outlet.

(Strathtay.) The valley of the Tay is also flanked by great terraces which may be traced from Pitlochrie (on the Tummel) and Logierait down to the Firth of Tay. It is quite apparent that these terraces were laved to their full extent by the waters of the ancient Firth, which at the height of 290 feet would flow up through Loch Tay.

Different Levels.—We give close approximations of the present levels above the sea, as taken in the centres of the different districts to which they refer.

1. Height at Logierait, 200 + 90 (height of terrace) = 290 feet (or maximum height of this supposed arm of the sea).
2. Height at Blair, 400 + 50 (height of terrace) = 450 feet (or maximum height of glacial lake).
3. Height in Glengarry, 710 + 30 (height of terrace) = 740 feet (or maximum height of glacial lake).
4. Height of Loch Tummel, 480 + 20 (height of terrace) = 500 feet (or maximum height of glacial lake).

Extent of Glacial Lakes.—This can be easily determined by the terraces.

1. The glacial lake of Glengarry was 3½ miles in extreme length, and ⅜ths of a mile in width.

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2. The glacial lake of Blair Athole was 7 miles in extreme length, and ½ a mile in width.
3. The glacial lake of Strathtummel was 6 miles in extreme length, and ¾ of a mile in width.

The Marine Theory.—The different levels of the terraces show that they are not ancient sea margins. The estuary's height in Strathtay was 290 feet above its present level. That it rose to this height may be also shown by the height at which shells occur along the Firth. The absence of marine shells in the higher terraces is also against the theory of marine origin.

The Soil.—The upland moors are largely composed of moss resting upon blue clay. The soil along the Garry is light and gravelly, especially at Blackisland, Invertilt, and Kingsisland, but immediately above the terraces the soil is exceedingly fertile even up to the higher slopes of the valley, where limestone occurs *in situ.* Rich alluvial soil prevails throughout Strathtummel and Strathtay.

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XII.—*Note, with Analysis, of a New Mineral from Cathkin Quarry, Glasgow.* By W. IVISON MACADAM, F.C.S., F.I.C., *Lecturer on Chemistry, Honorary Secretary.*

(Read 16th March 1882.)

The mineral to which this note refers was discovered by Mr Walter Burns in the Cathkin Quarries, south-east of Glasgow. Mr Burns has kindly furnished me, through Mr John Young, F.G.S., with a sample to lay before the Society, and also with fragments for analysis. In a letter received from Mr Young, the mineral is said to be "derived from the decomposition of a black, crystalline, basaltic Olivine Dolerite. 'The columns of the dolerite are about two feet in diameter, and stand in a vertical position. The quarry is near the summit of the Cathkin Braes, south-east of Glasgow." The mineral is of a dark chocolate brown, has a conchoidal fracture, and on being moistened splits up into fragments in a similar manner to Bolite.

Six analyses of the mineral were made, and the results are given in the table. Professor Heddle of St Andrews in a letter says:—"It is undoubtedly a much weathered variety of Saponite." In the Transactions of the Royal Society of Edinburgh, 1878-79, Professor Heddle gives an analysis of the unweathered saponite from the same locality.

ANALYSIS OF NEW VARIETY OF SAPONITE (CATHKIN QUARRY, GLASGOW).

Water	14·704	14·926	14·683	14·636	14·591	14·716
Silica	43·755	43·609	43·704	43·641	43·726	43·644
Ferric Oxide ...	36·206	36·061	36·301	36·286	36·271	36·316
Aluminic Oxide	0·041	0·055	0·052	0·047	0·053	0·044
Calcic Oxide ...	1·997	1·851	1·916	1·974	1·884	1·923
Magnesic Oxide	3·263	3·443	3·303	3·368	3·417	3·295
Undetermined ..	0·034	0·055	0·041	0·048	0·038	0·052
	100·000	100·000	100·000	100·000	100·000	100·000

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XIII.—*On the Discovery of Arctic Shells at High Levels in Scotland.* By RALPH RICHARDSON, F.R.S.E., *Vice-President.*

(Read 20th April 1882.)

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I. *Arctic Shell-Beds at High Levels in England and Wales.*—Moel Tryfaen, North Wales, 1392 ft.; Snowdon, North Wales, 1300 ft.; Vale Royal, near Macclesfield, 1150 ft.; Mottram, near Manchester, 568 ft.
II. *Arctic Shell-Beds at High Levels in Ireland.*—Caldbeck Castle, near Ballyedmonduff, 1300 ft.
III. *Arctic Shell-Beds at High Levels in Scotland.*—Chapelhall, near Airdrie, Lanarkshire, 510 ft.; Drummore of Clava, Inverness-shire, 500 ft., and Ardersier, Fort-George, 50 ft.; The Ord, near Portsoy, Banffshire, 400 ft.; near Stornoway, Isle of Lewis, 350 ft.; Airdrie, Lanarkshire, 350 ft.; near Loch Lomond, 320 ft.; Arran, 320 ft.; Auchleuchries, Aberdeenshire, 300 ft.; Caithness Boulder Clay, rising to 200 ft.; Gamrie, near Banff, 150 ft.; King Edward, near Banff, 150 ft.; Tangy Glen, near Campbeltown, Argyll, 130 ft.; Ellishill, near Peterhead, 120 ft.; Croftamie, Dumbartonshire, 100 ft.; Kilmaurs, near Kilmarnock, 90 ft.
IV. *List of Arctic Shell-Beds at Lesser Levels in Scotland.*
V. *List of Arctic Shells from Scottish High-Level Beds mentioned in this Paper, with Localities and Elevations.*
VI. *Arctic Shell-Bed Map of Scotland to illustrate this Paper.*

Probably no proof that a glacial climate once prevailed in our country has been more convincing than the discovery of Arctic shells at various levels throughout the United Kingdom. The subject has been very ably investigated in Scotland by such well-known geologists as James Smith of Jordanhill, Charles W. Peach of Edinburgh, T. F. Jamieson of Ellon, David Robertson and Rev. H. W. Crosskey of Glasgow, Rev. Thomas Brown of Edinburgh, and Dr James Geikie, Robert L. Jack, Benjamin N. Peach, and John Horne of the Geological Survey of Scotland. The originator of this line of research in Scotland was the late Mr James Smith of Jordanhill, who discovered in inland deposits throughout the west of Scotland a number of shells unknown to local collectors, which were submitted to M. Deshayes, the eminent French conchologist, and recognised by him as living Arctic shells. "This clue," said Mr Bennie, "being followed out, the great fact was established by Mr Smith in 1839 that, during the times represented by these shell-beds, the climate of Scotland was half Arctic in its character." *

Most of the discoveries in Scotland of Arctic shells have been

* "Trans. Geol. Soc. Glasgow," vol. ii., p. 101.

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made at low levels, such as on the sea-shore, or at a small elevation above it. I propose to show in this paper, however, that the Arctic sea which once existed in these latitudes submerged Scotland to a very considerable extent. For this purpose I shall, after glancing at similar discoveries in England and Wales and Ireland, bring under your notice the various localities at high levels in Scotland where the shells which lived in that Arctic sea have been discovered. I may add that we have proofs that that sea submerged, during the glacial period, not merely a large portion of the British Isles, but extended, in Europe, as far south as the Alps and Carpathians; in Asia, over Siberia; and in America, over a considerable part of the Northern Continent.*

Arctic Shell-Beds at High Levels in England and Wales.

Moel Tryfaen, North Wales, 1392 *feet.*—With regard to England and Wales, Sir Charles Lyell, in his "Antiquity of Man," † mentions several exceedingly high levels at which Arctic shells have been found. He states that in 1831 Mr Trimmer discovered marine shells on Moel Tryfaen, North Wales, in glacial drift 1392 feet above the sea. Sir Charles visited this locality in 1863, and found a mass of stratified sand and gravel 35 feet thick, containing, among others, the following Arctic shells:—

Arctic habitat.

** Astarte borealis—Iceland, Finmark, and Greenland.
** „ crebricosta—Spitzbergen, Finmark, and Newfoundland.
* „ elliptica—Greenland, Finmark, and Spitzbergen.
* „ compressa—Nova Zembla and Greenland.
** Leda rostrata—Spitzbergen, Finmark, and Arctic America.
** Natica clausa—Finmark, Nova Zembla, and Greenland.
** Tellina calcarea—Finmark, Greenland, and Behring's Straits.
** Trophon clathratus—Greenland, Russian Lapland, and Behring's Straits.
** „ scalariformis—Spitzbergen, Newfoundland, and Behring's Straits.
** „ Gunneri—Finmark and Greenland.

** British species (fossil).
* British species (living).

I have cited the above localities for these shells as given in Dr Woodward's "Manual of the Mollusca," ‡ and shall continue

* Dr Woodward's "Manual of the Mollusca," second edition, 1868, p. 57.
† Fourth Edition, 1873, p. 313.
‡ Second Edition, 1868, p. 59.

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to depend upon that excellent authority during this paper. Of course, some shells are not exclusively Arctic, but are found in British waters as well. I shall only cite shells now living in Arctic regions, calling attention, however, to such of them as likewise belong to living British species. In the lists given in this paper, Arctic shells found in Britain only in a fossil state are marked by a double asterisk (**), whilst Arctic shells found living at this day in British waters are marked by a single asterisk (*).

Snowdon, Wales, 1300 *feet; Vale Royal, near Macclesfield,* 1150 *feet; Mottram, near Manchester,* 568 *feet.*—Professor Ramsay, lately Director-General of the Geological Surveys of the United Kingdom, and now bearing the well-merited title of Sir Andrew Ramsay, found marine shells in the vicinity of Snowdon, Wales, at a height of about 1300 feet above the sea; whilst Professor Prestwich discovered them in glacial drift between 1100 and 1200 feet high at Vale Royal, near Macclesfield. Arctic shells were also found at Mottram, near Manchester, in till 568 feet above the sea.*

The altitudes just given are exceptionally great; indeed, I believe that Arctic shells have not been found in Britain at greater heights than those just mentioned, viz.:—

	Feet.
At Moel Tryfaen, North Wales, . .	1392
Near Snowdon, do. . .	1300
At Vale Royal, near Macclesfield, .	1150
At Mottram, near Manchester, . .	568

Arctic Shell-Beds at High Levels in Ireland.

Caldbeck Castle, near Ballyedmonduff, 1300 *feet.*—Crossing the Irish Sea, we find on the flanks of the Dublin and Wicklow Mountains interglacial gravels at high levels containing some of the Arctic shells which occur at similar levels in North Wales. Professor Hull, the Director of the Irish Geological Survey, mentions † that shells have been found at an elevation of 1300 feet at Caldbeck Castle, near Ballyedmonduff, and in the Killakee Valley. The shells found at Moel Tryfaen, North Wales, at a level of 1392 feet, were more decidedly Arctic in their facies, still two of the same genius (both British living shells) occur in both localities, viz., *Astarte compressa* and *Astarte elliptica.* It is interesting to find, both in North Wales and

* Lyell's "Antiquity of Man," cited *supra.* In a letter to Sir Charles Bunbury in August 1874, Lyell states that he had visited the shell-bed near Macclesfield, and found that it contained more than fifty shells, "all of recent species, and by no means like those of Moel Tryfaen" (74 miles distant); "as a whole, very glacial."—*Letters,* 1881, vol. ii., p. 449.

† "Physical Geology and Geography of Ireland," 1878, p. 86.

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East Ireland, at a height of 1300 feet, and many miles apart, these evidences of very different physical conditions than at present obtain there.

Arctic Shell-Beds at High Levels in Scotland.

The result of the evidence afforded by Welsh and Irish fossils seems to be to show that an Arctic Sea once covered North Wales and East Ireland to a height of upwards of 1300 feet above the present sea-level. Proceeding next to our review of similar phenomena in Scotland, I may state at once that we find no evidence of so great a submergence there. Indeed, so far as fossil proofs go, we have as yet no evidence that Scotland was submerged by an Arctic Sea to a greater extent than a little over 500 feet above the present sea-level. There is thus a difference of about 800 feet between the respective highest levels of Arctic shells discovered in Wales and Ireland and Scotland. It would be an interesting physical problem to attempt to explain why there should be such a great difference in the depth of the submergence of North and South Britain. Could the same Arctic sea have submerged Wales to the extent of 1300 feet, and Scotland only to that of 500 feet? Or may future discoveries not perhaps prove to us that the Arctic Sea covered Scotland to a much higher level than 500 feet? Lyell suggests that the absence of marine shells in Scotland at a greater height than a little above 500 feet "may, in part perhaps, be ascribed to the action of glaciers which swept out marine strata from all the higher valleys, after the re-emergence of the land."* Dr James Geikie, however, thinks that "marine interglacial beds may yet be found at higher levels" than 500 feet in Scotland.† I confess I do not favour Lyell's "sweeping-out" hypothesis; for it is difficult to believe that the operations of the glaciers would be so searching and complete as not to leave some traces, however small, of the marine deposits at higher levels than 500 feet. I prefer to think that, in course of time, Arctic shell-beds will be discovered in Scotland at much higher levels than 500 feet; and thus Scotland will approximate to the very great subsidence attested by the shell-beds of Wales and Ireland. At the same time, the submergence of Scotland by an Arctic sea to the extent of 500 feet, indicates very great physical and climatic changes. I proceed to the proofs of this extraordinary event in our country's history. It occurred, I need hardly add, during that period which has been designated by Dr James Geikie the "Great Ice Age," immediately preceding the last stage of geology when the earth gradually acquired its present configuration.

* "Antiquity of Man," Fourth Edition, p. 290.
† "Great Ice Age," Second Edition, p. 329.

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Chapelhall, near Airdrie, Lanarkshire, 510 *feet*.—The highest discovery of Arctic shells yet recorded in Scotland, was described by Mr Smith of Jordanhill, in a paper read before the Geological Society of London in 1850, and republished in his classical little work, "Researches in Newer Pliocene and Post-Tertiary Geology." * This discovery occurred, according to Dr James Geikie,† at Chapelhall, near Airdrie, Lanarkshire, although Mr Smith himself only describes the locality as "near the Monkland Iron Works, and about 14 miles to the south-east of Glasgow." Mr Smith states, that at the depth of 14 feet from the surface (524 feet), after passing through the till, a bed of brickclay was reached containing Arctic shells, which were therefore 510 feet above the level of the sea. The shelly deposit proved to be a bed of *Tellina calcarea* (or *proxima*) which is not a living British species, but is now found living in Finmark, Greenland, and Behring's Straits. Mr Smith adds, that the till beneath which he discovered these shells was "unquestionably the true till." I have two remarks to make upon this statement. In the *first* place, the section of Chapelhall described by Mr Smith, was subsequently examined by as excellent an observer, viz., Rev. H. W. Crosskey, who, in a paper read before the Geological Society of London in 1865,‡ said that he had formed the opinion that the Arctic shell-bed at Chapelhall was not (as Mr Smith supposed) below, but *above* the till, the bed which Mr Smith termed "till" being probably a clay of later deposit than the till. The section at Chapelhall, as given by Mr Crosskey, is, in descending order, as follows :—

Clay (supposed by Mr Smith to be till).
Finer clay, containing *Tellina calcarea* (purely Arctic), *Cyprina Islandica* (British as well as Arctic).
Till, resting on carboniferous rocks.

In the *second* place, we must define what we mean by "till." Dr James Geikie, the leading authority on glacial geology, defines till as "the lowest lying, and therefore the oldest of the superficial deposits of Scotland." § Dr Geikie, or rather according to the dignity he now so worthily holds, Professor James Geikie ‖ has, after long study of the glacial epoch, divided it chronologi-

* Glasgow, 1862, p. 140. See also Rev. Mr Crosskey's Paper on this section in "Q. J. G. S." (1865), vol. xxi. p. 219.
† "Great Ice Age," 2d edition, p. 605.
‡ "Q. J. G. S.," vol. xxi. p. 219.
§ "Great Ice Age," p. 59.
‖ Succeeded his brother Archibald as Professor of Geology and Mineralogy in the University of Edinburgh, January 1882, his brother succeeding Professor Ramsay as Director-General of the Geological Surveys of the United Kingdom.

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cally into four periods, which followed each other in this sequence :—

1*st.* A period of intense Arctic rigour, when the whole country was covered with ice, underneath which was formed, as its ground-moraine, the deposit of boulder clay termed *till.*

2*nd.* An interglacial period when the icesheet retreated to the mountains, streams flowed in the valleys, and the mammoth and reindeer lived.

3*rd.* A second interglacial period, when the sea rose 100 feet at least, and when Arctic molluscs lived and were buried in silt and sand.

4*th.* A period when intense Arctic conditions again prevailed, and a vast icesheet again enveloped the country, and formed as its ground-moraine a second deposit of boulder clay.

Now, here we have two deposits of boulder clay, formed in precisely the same way, viz., by the grinding action of an icesheet. To the former alone of these deposits, Dr Geikie applies the distinctive title of "till." He is of opinion that the Arctic shell-beds under notice belong to the second interglacial period, that is to say, they lie above the till formed by the first icesheet, but below the boulder clay formed by the second icesheet.* Returning, therefore, to the Chapelhall section, and applying Dr Geikie's theory to it, we would say that the boulder clay which Mr Smith called "till," was the result of the second icesheet; that the Arctic shellbed which was found under it was of interglacial age; and that the boulder clay which Mr Crosskey discovered beneath the shellbed was the *till*, the result of the first icesheet. Another eminent Scotch geologist, Mr T. F. Jamieson, of Ellon, has expressed a similar opinion to that of Dr Geikie. In a valuable paper, entitled "Last Changes in Scotland," read before the Geological Society of London in 1865,† Mr Jamieson recognises, from evidence furnished by marine shells, a submergence in Scotland up to 500 feet above the present sea level; and considers that the depression of the land hundreds of feet beneath the sea level, and the deposit of brick clays, containing Arctic shells, occurred *after* the till had been formed and deposited by the action of land ice. Indeed, the only criticism I would venture to make upon Dr Geikie's theory is, that the words describing the second interglacial period, "when the sea rose 100 feet at least," might be altered

* The Rev. Thomas Brown states, in his paper on the Arctic Shell-Clay of Elie and Errol, that that celebrated geologist, the late "Dr Fleming, showed that there are earlier and later boulder clays; and this is quite plain when we contrast that of Errol, underlying the shell clay, with that of Caithness as investigated by Mr Peach." "Trans. R. S. E.," vol. xxiv. p. 617 (1867).

† "Q. J. G. S.," vol. xxi. p. 170.

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to "500 feet," that being the level evidenced by marine shells. The climate of this marine interglacial period would resemble that of the Arctic regions to-day; and the molluscs, which are now found in Arctic waters only, would then inhabit a vast ocean, whose southern shores would, in Europe, be the Alps and Carpathians, which, in Asia, would cover Siberia, and further east would submerge a large portion of North America.

Drummore of Clava, Inverness-shire, 500 *feet.*—Since the year 1850, no discovery of Arctic shells at very high levels in Scotland, had been announced till last July (1881), when, at a conference of northern scientific societies at Elgin, at which I was privileged to be present, a discovery of Arctic shells at Drummore of Clava, Inverness-shire, 500 feet above the sea, was intimated in a letter from the discoverer, Mr James Fraser, C.E., Inverness, read at the meeting. In that letter * Mr Fraser stated, that he found the shells "under the boulder clay," and that the section consisted of the following beds in descending order :—

Later gravelly drift to some depth.
30 or 40 feet of yellow boulder clay, containing stones, some of which are ice-scratched.
12 feet of hard yellow or brown sand, bearing some marks of stratification, and compacted together to the hardness of brick clay.
A bed of blue clay or silt, containing Arctic shells.
Under deposit not yet determined.

A paper upon this interesting section and its shells, by Mr Fraser, was read before our Society on 17th November last. The Arctic shells discovered here by Mr Fraser, were examined by Messrs Jamieson of Ellon, and Robertson of Glasgow, at Mr Fraser's request, and the following is the list of species determined :—

Arctic habitat.

** Leda pernula—Finmark, Spitzbergen, and Arctic America.
* Leda pygmæa—Greenland, Finmark, and Siberia.
** Pleurotoma turricula—Greenland.
** Tellina Balthica — Nova Zembla, Spitzbergen, Finmark, Greenland, Behring's Straits.
* Buccinum undatum—Ochotsk.
* Natica Grœnlandica—Greenland, Norway, Spitzbergen.
** Trophon clathratus—Russian Lapland, Greenland, Behring's Straits.
* Cardium edule—Russian Lapland.
* Mytilus edulis—Russian Greenland, Behring's Straits.

In all, 4 Arctic and not British living species; and 5 both

* *See* Report of Conference given in *Inverness Courier* of 2d August 1881.

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British and Arctic living species. I inspected this section last August, after seeing Mr Fraser, who kindly pointed out the locality on the Ordnance Survey map. In appearance, the "blue clay or silt," containing the shells, resembled the blue till with which we are so familiar in Midlothian. It was an unstratified tenacious clay full of rounded and polished pebbles. Mr Wallace, Rector of the High School, Inverness, and Secretary to the Elgin Conference, informed me that similar blue clay, containing Arctic shells, occurred near Fort George, which is on the sea coast, about 8 miles due north of Mr Fraser's 500 feet section.

A paper, by Mr Wallace, relative to this sea-coast section, was also read before our Society on 17th November last. He informed us in it, that Mr Jamieson, of Ellon, had in 1865 found the following Arctic shells, at a height of from 45 to 50 feet, in blue clay, near Ardersier Manse, Fort George:—

Arctic habitat.

** Leda pernula—Finmark, Spitzbergen, Arctic America.
** Tellina calcarea—Finmark, Greenland, Behring's Straits.
* Astarte elliptica—Finmark, Greenland, Spitzbergen.

Leda pernula, an Arctic and not British living species, thus occurs both at Clava and Fort George, proving that both localities had once been covered by an Arctic sea, of a temperature similar to that now washing the coasts of Arctic America, Finmark, and Spitzbergen.

By Mr Wallace's directions, and holding his admirable scientific sketch-map * of the Inverness district in my hand, I drove last August from Inverness *via* the Druid's Temple and General Wade's Military Road to Strathnairn; crossing the river Nairn at the bridge near Daviot Church, and driving along its right bank to the huge "Tom-riach" boulder,† one of the largest in Scotland. Returning, I inspected Mr Fraser's section, and crossing the river again at Clava, after viewing its archæological wonders, the road back to Inverness lay over the celebrated battlefield of Culloden. I observed that the whole valley of the Nairn bore evident traces of having known, during a comparatively recent geological period, very different physical conditions to the present. Erratics strew,

* This was a lithographed map of the district, prepared by Mr Wallace, showing, besides the leading roads and villages, the locality of every known object of geological and archæological interest, *e.g.*, rock exposures, boulders, glacial striæ, hill forts, ruins, cup-marked stones, &c. If we had a series of such maps prepared for the United Kingdom, it would immensely increase the interest and profit of travelling.

† Mr Fraser, in his paper on "Recent Formations of Strathnairn" ("Trans. Edin. Geol. Soc.," vol. iv. p. 64, 1881), translates this "the stone of the grey hill." It is a Conglomerate erratic, resting on gneiss 400 feet above the sea, and weighing above 500 tons. He remarks that travelled boulders are found in Strathnairn up to 1800 feet or higher.

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and sand covers, the hill-sides to a great height, proving the submergence of the country to a very considerable depth (more than 500 feet above the sea level) during one of the last geological periods. The Inverness district is an extremely interesting one, both geologically and archæologically; and the conference of scientific societies to be held this year in Inverness, under the genial management of Mr Wallace, the convener and secretary, ought to be one of the most attractive scientific gatherings of the year. I trust that our Society, which is so much indebted to Inverness geologists, such as Messrs Fraser and Wallace, for interesting and valuable papers, full of original research, and bearing evidence of painstaking investigation, will be well represented at the Inverness Scientific Congress, which the members of our Society are all invited to attend.

At the Ord, near Portsoy, Banffshire, 400 *feet.*—A discovery of Arctic shells, at levels between 400 and 450 feet, was recently made by Mr John Horne, of the Scotch Geological Survey, and presently stationed at Huntly. He found them at that height, at the Ord, about 5 miles south-east of Portsoy, Banffshire, in beds of finely stratified sand, which he considered to be of interglacial age, and to indicate a depression to the extent of 500 feet, on the south side of the Moray Firth, in interglacial times; for the fossiliferous sands can be traced southwards from the Ord to a height of 500 feet, where they are partly covered with boulder clay. He announced this discovery in a valuable paper, by himself and Mr B. N. Peach, which was read before the Royal Physical Society last April (1881).* I had the pleasure of meeting Mr Horne at the Elgin Conference, and can testify to his rare powers of observation and exposition. You may remember the admirable paper on the Geology of the Isle of Man, which he read before our Society in February 1874,† and in which he describes shelly brick-clays, adding, on the authority of Mr R. Etheridge, jun., that the glacial shells of the Isle of Man agree, on the whole, with those commonly met with in our Scotch glacial clays.

Near Stornoway, Isle of Lewis, 350 *feet.*—As to the Outer Hebrides, I have recently learnt that that veteran geologist, Mr David Robertson, of Glasgow, found in August 1879, a considerable number of marine foraminifera, indicating glacial conditions, between Stornoway and Barvas, Isle of Lewis, under gravel, between 300 and 400 feet above the sea. With regard to the Orkney Islands, Messrs Peach and Horne frequently found Arctic shell fragments throughout the boulder clay there.‡

* Peach and Horne on "The Glaciation of Caithness," "Pro. Royal Phys. Soc. Edin.," vol. vi. p. 350.

† "Trans. Edin. Geol. Soc.," vol. ii. p. 346.

‡ Paper on "The Glaciation of the Orkney Islands," "Q. J. G. S.," vol. xxxvi. p. 656 (1880.)

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At Airdrie, Lanarkshire, 350 *feet.*—I have already mentioned the discovery of Arctic shells at Chapelhall, near Airdrie, at a height of 510 feet, being, as yet, the highest found in Scotland. Mr Smith, of Jordanhill, likewise describes a discovery of Arctic shells "at Airdrie, about 10 miles to the east of Glasgow, at a height of 350 feet; they were found between a mass of blue till and a bed of yellow stratified clay which rested upon it." * An Arctic shell not now found living in Britain, viz., *Tellina calcarea* (or *proxima*), was obtained from this Airdrie bed as well as from that at Chapelhall.

Near Loch Lomond, 320 *feet.*—In a paper read before the Geological Society of Glasgow in 1874,† Mr Jack, of the Geological Survey, describes various beds in the lower valley of the Endrick, near Loch Lomond, the lowest being a stratified clay containing marine shells at Croftamie (which I shall refer to afterwards); above that a "shelly till" traceable by means of broken shells which it contains to a height of 320 feet; and above that stratified mud, clay, sand, and gravel, which yielded at three localities 120, 160, and 210 feet respectively above the sea, water-worn shells, all now living in British seas. He states that fragments of the following shells were found in the shelly till:—

Arctic habitat.

* Cyprina Islandica—Russian Lapland, Labrador.
** Trophon clathratus—Russian Lapland, Greenland, Behring's Straits.
* Astarte compressa—Nova Zembla, Greenland.
* Astarte sulcata—Russian Lapland, Nova Zembla, Ochotsk.

The last was found at the height of 320 feet. He considers that these shells became embedded in this till owing to the icesheet which produced it, corresponding to Dr James Geikie's second icesheet, having swept them out of an interglacial or preglacial shell bed.

In the Island of Arran, 320 *feet.*—The Rev. R. B. Watson, in a paper read before the Royal Society of Edinburgh, in January 1864, describes the great drift beds, with shells, in the south of the interesting and beautiful island of Arran.‡ He remarks:—"Shells occur occasionally in considerable quantities both in the boulder clay and in the sandy clay (not in the glacier gravel) below, at various heights from 80 to 320 feet above the sea." From a list of these shells appended to his paper, I extract the following Arctic species:—

* "Researches," p. 17.
† "Trans. Geol. Soc., Glas.," vol. v. p. 24.
‡ "Trans. R. S. E.," vol. xxiii. p. 523.

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Arctic habitat.

** Tellina Balthica (Grœnlandica)—Nova Zembla, Spitzbergen, Finmark, Greenland, Behring's Straits.
* Cyprina Islandica—Russian Lapland, Labrador.
* Astarte elliptica—Finmark, Greenland, Spitzbergen.
** Astarte arctica—Finmark.
* Astarte compressa—Nova Zembla, Greenland.
* Modiola modiolus—Russian Lapland, Behring's Straits.
* Leda pygmæa—Greenland, Finmark, Siberia.
** Leda pernula—Finmark, Spitzbergen, Arctic America.
** Pecten Islandicus—Finmark, Nova Zembla, Spitzbergen, Greenland, Behring's Straits, St Lawrence.

In all, 4 species not now found living in Britain, and 5 species which are found living there as well as in Arctic regions. Our former vice-president, Dr Bryce, in his "Geology of Arran," * refers to a clay bed with Arctic shells above boulder clay at the Cloinid burn, near Lag.

At Auchleuchries, Aberdeenshire, 300 *feet.*—Mr Jamieson of Ellon, in his paper on "Last Changes in Scotland," before alluded to,† says that the greatest height at which he had met with fossil shells in Aberdeenshire is 300 feet, "in this instance in a deep mass of stratified gravel forming the crest of a low hill about five miles from the sea." I infer, from an explanatory note appended to his paper, that this was at Auchleuchries, described there as "twenty miles north of Aberdeen, and seven miles inland." After referring to Arctic shells found at a lower level (150 feet) at Gamrie, in Banffshire, to which I shall presently allude, he continues: "These are the highest positions known to me of marine fossils in the glacial beds of the north of Scotland." It is satisfactory to know that since 1865 geological discovery has revealed shells at considerably higher elevations in the north of Scotland. Mr Jamieson recognises, from evidence furnished by marine shells, a "submergence in Scotland up to 500 feet above the present sea-level." He is of opinion that the depression of the land hundreds of feet beneath the sea-level and the deposit of brick-clays containing Arctic shells, occurred *after* the till had been formed and deposited by the action of land-ice. The following Arctic shells were found at Auchleuchries:—

Arctic habitat.

** Astarte borealis—Finmark, Iceland, Greenland.
* Cyprina Islandica—Russian Lapland, Labrador.
* Purpura lapillus—Russian Greenland, Behring's Straits.

* 4th edition, pp. 181 *et seq.*
† Quarterly Journal Geological Society, xxi., p. 170.

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As he stated in a paper read before the Geological Society of London on 8th March last ("Quarterly Journal Geological Society," vol. xxxviii., p. 147), Mr Jamieson found Arctic shells near Auchleuchries, at Leask, at a height of 225 feet, and at the Loch of Slains at a height of 136 feet in a tract of shelly gravel to the north of the river Ythan. In this "Slains gravel" he discovered—

Arctic habitat.

* Cardium edule—Russian Lapland.
* Cyprina islandica—Russian Labrador.
* Fusus antiquus—Nova Zembla, Behring's Straits.
** „ carinatus—Greenland.
* „ contrarius—Russian Lapland, Ochotsk.
* Purpura lapillus—Russian Greenland, Behring's Straits.
** Tellina Balthica—Nova Zembla, Spitzbergen, Finmark, Greenland, Behring's Straits.

In the Caithness Boulder-Clay, occasionally rising to 200 *feet.*—We now come to a singular deposit, viz., the Boulder-clay of Caithness, in which Arctic shells are found in a more or less perfect state of preservation. Mr Dick of Thurso, and our esteemed Associate Mr Charles W. Peach (both of whom Dr Smiles has immortalised),* as well as Hugh Miller, investigated this field many years ago. By the kindness of Mr Stock, I was lately enabled to see in the "Hugh Miller Collection" in the Edinburgh Museum of Science and Art many of the Arctic shells discovered by Dick and Miller in this Caithness boulder-clay, which Dr James Geikie says "rises in many places to a height of 200 feet above the sea-level, and varies in thickness from sixty to eighty feet." † Mr Jamieson of Ellon,‡ and Messrs Crosskey and Robertson,§ have likewise described it and its shells; but its latest investigators are Mr Benjamin N. Peach (son of Mr Charles) and Mr John Horne, both of the Geological Survey of Scotland, who described it in their exhaustive paper on "The Glaciation of Caithness," read before the Royal Physical Society last April (1881).‖ So long ago as 1802, a Mr John Busby, Edinburgh, published a "Mineralogical Survey" of Caithness, in which he mentions finding "blue clay-marl intermixed with marine shells in great abundance." ¶ Messrs Peach and Horne divide the boulder-clay of Caithness into "two dis-

* "Robert Dick, Baker of Thurso, Geologist and Botanist." By Samuel Smiles. 1878. (Contains also a Biography and Portrait of Mr C. W. Peach, A.L.S.)
† "Great Ice Age," second edition, p. 604.
‡ "Quarterly Journal Geological Society," xxii., p. 261. 1868.
§ "Transactions Geological Society, Glasgow," iii., p. 125. 1868.
‖ "Proceedings Royal Physical Society," vi. 316. 1881.
¶ Hugh Miller's "Rambles of a Geologist," p. 313. 1858.

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tinct types," viz., 1st, A stiff, dark grey, shelly boulder-clay occurring over the whole of a triangular-shaped area of about 300 square miles lying to the east and north of a line drawn across Caithness from Shebster to Dunbeath; and, 2nd, A reddish or brown boulder-clay containing no shells, occurring to the west and south of said line. As the list which I have appended to the present paper shows (page 200), the Caithness boulder-clay contains almost every species of Arctic shell found at high levels in Scotland. Messrs Peach and Horne give a long list of organisms from the Caithness boulder-clay prepared from the papers of previous investigators, and for brevity I shall cite only those Arctic shells in their list which are not now found living on British shores, viz. :—

Arctic habitat.

Dentalium entale—Spitzbergen.
Natica affinis (clausa) — Finmark, Nova Zembla, Greenland, Behring's Straits, Melville Isle, Prince Regent's Inlet.
Natica pallida—Russian Lapland, Ochotsk.
Trophon clathratus—Russian Greenland, Behring's Straits.
Astarte borealis (arctica)—Finmark, Iceland, Greenland.
Cardium Grœnlandicum—Kara, Spitzbergen, Cape Parry, St Lawrence.
Leda minuta—Finmark, Spitzbergen, Greenland, Davis Straits.
Leda pernula—Finmark, Arctic America.
Pecten Islandicus—Finmark, Nova Zembla, Spitzbergen, Behring's Straits, St Lawrence.
Saxicava rugosa—Nova Zembla, Spitzbergen, Greenland, Cape Parry, Behring's Straits.
Tellina calcarea—Finmark, Greenland, Behring's Straits.
Tellina Balthica—Finmark, Greenland, Nova Zembla, Spitzbergen.
Rynchonella psittacea—Russian Lapland, Baffin's Bay, Melville Isle, Behring's Straits.

Besides these, there were eighteen species of Arctic shells which are also found living in Britain. As to the question of how the Caithness boulder-clay came to be crowded with marine organisms if it was the product of land-ice, Messrs Peach and Horne hold that its origin was due to a Scandinavian *mer de glace* which, crossing the bed of the North Sea, bore inland over Caithness pebbly mud and marine shells commingled with flagstone debris, and preglacial or interglacial marine deposits.*

At Gamrie, near Banff, 150 *feet*.—So long ago as 1837, Professor Prestwich, in a paper read before the Geological Society

* Paper cited, p. 351.

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of London,* announced his discovery of Arctic shells in a series of sands and clays at Gamrie, about nine miles east of Banff. He has kindly sent me a copy of his original paper, adding, in a letter, that the shells he found are more correctly named in Mr Smith's "Researches," to which I have previously referred. Mr Jamieson has also discussed † the Gamrie section, and states that Professor Prestwich found the shells at the height of 150 feet (not 350 feet, as Mr Smith said), although the beds of sand and clay containing them reach to nearly 660 feet, the height attained by the stratified gravel in which the shells were found at Auchleuchries. Turning to Mr Smith's "Researches,"‡ we find the following Arctic shells—both living British species, however—noted as found at Gamrie by Professor Prestwich:—

Arctic habitat.

Astarte sulcata (Scotica)—Russian Lapland, Nova Zembla, and Ochotsk.
Buccinum undatum—Kara, Ochotsk.

Mr Smith adds:—"I examined, along with Professor Edward Forbes, Mr Prestwich's shells, and found they belong to the glacial epoch." I may mention that Gamrie is one of the localities of the shells contained in the Hugh Miller Collection in the Edinburgh Museum of Science and Art. Miller described the Gamrie shell-bed in a lecture delivered before the Edinburgh Philosophical Institution, § giving it a height of 230 feet, and stating that he had found in it the following Arctic shells, not now living in Britain:—

Arctic habitat.

Astarte borealis (arctica)—Finmark, Iceland, Greenland.
Tellina calcarea (proxima)—Finmark, Greenland, Behring's Straits.
Natica clausa—Finmark, Greenland, Nova Zembla.

He also found *Cyprina Islandica* and *Modiola modiolus*, Arctic British shells.

At King Edward, near Banff, 150 *feet*.—Not far from Gamrie is the village of King Edward, and near there Mr Jamieson found the following Arctic shells in silt overlaid by unstratified boulder-clay, the upper surface of the silt being 150 feet above the sea: ‖—

* "Transactions," 2nd Series, vol. v., p. 139; and Appendix, p. 147.
† "Quarterly Journal Geological Society," xxi., p. 170.
‡ Page 18.
§ "Edinburgh and its Neighbourhood." 1864. Pp. 24 and 31.
‖ "Quarterly Journal Geological Society," xxi. 197; and xxii. 275.

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Arctic habitat.

** Astarte borealis—Finmark, Iceland, Greenland.
** Cardium Grœnlandicum—Spitzbergen, Cape Parry, St Lawrence.
* Cyprina Islandica—Russian Lapland, Labrador.
** Dentalium entale—Spitzbergen.
* Lacuna vincta—Russian Lapland, Newfoundland, Greenland.
** Leda lucida—Spitzbergen.
* Mya truncata—Russian Lapland, Spitzbergen, Cape Parry, Behring's Straits.
** Natica pallida—Russian Lapland, Ochotsk.
* Natica pusilla (Grœnlandica)—Greenland, Norway, Spitzbergen.
** Scalaria Grœnlandica—Finmark, Greenland, Behring's Straits.
** Tellina Grœnlandica (Balthica)—Nova Zembla, Spitzbergen, Finmark, Greenland, Behring's Straits.
** Tellina calcarea—Finmark, Greenland, Behring's Straits.
** Trophon clathratus—Russian Lapland, Greenland, Behring's Straits.
*Trophon truncatus.

In all, nine species not now living, and five living in British seas.

Mr Horne's discovery, before mentioned, at The Ord, Banffshire, was only about five miles north-west of King Edward. He found Arctic shells in finely stratified sands which passed beneath the boulder-clay. At King Edward also, the shelly silt underlies the boulder-clay. According to Dr James Geikie's theory, this boulder-clay is the result of the second icesheet, the shells having been deposited during an interglacial period. Both Mr Jamieson and Mr Horne, as I have already mentioned, accept this theory as the correct one, and do not consider that this boulder-clay is the same as the till which was the result of the first icesheet and underneath which shells have not been discovered.

At Tangy Glen, near Campbeltown, Argyll, 130 *feet.*—A section not dissimilar to the foregoing is described by those very thorough workers, Messrs Crosskey and Robertson of Glasgow.* It occurs at Tangy Glen, near Campbeltown, Argyllshire, where Arctic shells were found, 130 feet high, in grey laminated clay overlaid by boulder-clay. The authors remark that "the chief interest of this section consists in the fact that, contrary to the usual position of the boulder-clay in the west of Scotland, here it overlies shell-bearing clay." They add: "Taken along with the well-known Kilmaurs and Croftamie beds" (to which I shall presently refer), "the deposit in Tangy Glen seems to be

* "Transactions Geological Society, Glasgow," iv., p. 134.

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another well-marked instance of marine clay with Arctic shells underlying boulder-clay; and we have no doubt, as there are now more workers in this field of research, that additional instances of the same kind will be disclosed." Apparently Messrs Crosskey and Robertson do not subscribe to Dr James Geikie's opinion that Arctic shells are not found beneath the till or older boulder-clay, for I understand that they consider the "boulder-clay" at Tangy Glen to be till, for they state that, in their series of papers, they specially restrict the term *Boulder-clay* to the older deposit of the Scotch glacial series,* which is, I presume, what Dr Geikie calls *till.* The Arctic shells found at Tangy Glen were as follows:—

Arctic habitat.

** Pecten Grœnlandicus †—Russian Lapland, Spitzbergen, Davis Straits.
* Leda pygmæa—Greenland, Finmark, Siberia.
** Leda pernula—Finmark, Spitzbergen, Arctic America.

Dr James Geikie, reviewing the Tangy Glen, and similar instances of shell-beds below boulder-clay,‡ refuses to think that these shell-beds are preglacial. In fact, considering the strong grinding action of several successive ice-sheets, he doubts whether any portion of the old preglacial surface of the country has been preserved. He thinks it more reasonable to believe that those shell-beds belong to the latest interglacial period immediately preceding the final great extension of land-ice.

At Ellishill, near Peterhead, 120 *feet.*—Mr Jamieson mentions§ that the following Arctic shells were found in red clay in a railway cutting at Ellishill, three miles west of Peterhead, Aberdeenshire, about 120 feet above the sea, viz.:—

Arctic habitat.

* Cardium edule—Russian Lapland.
* Cyprina Islandica—Russian Lapland, Labrador.
* Mytilus edulis—Russian Greenland, Behring's Straits.
** Pecten Islandicus—Finmark, Nova Zembla, Spitzbergen, Greenland.
** Saxicava rugosa — Nova Zembla, Spitzbergen, Greenland, Cape Parry.

At Croftamie, Dumbartonshire, 100 *feet.*—We pass next to a

* "Transactions Geological Society, Glasgow," iv., p. 33.
† The authors remark that this was the first discovery of this shell on the west coast of Scotland, although found in the glacial beds of Montrose, Elie, and Errol on the east coast.
‡ "Great Ice Age," p. 173. § "Q. J. G. S.," vol. xxi. p. 196.

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discovery which has elicited a good deal of attention. In 1858 Dr John A. Smith, the well-known antiquary, described* a section which occurred in a cutting of the Forth and Clyde Railway, 100 feet above the sea, at Croftamie, near Drymen station, four miles from Loch Lomond. He stated that the section consisted of a stiff till 12 feet thick, beneath which was a deposit of blue clay about 7 feet thick, immediately overlying sandstone *in situ.* Resting on the sandstone, and consequently under the blue clay, the following Arctic shells (all species now living in Britain) were discovered.

Arctic habitat.

* Astarte elliptica—Finmark, Greenland, Spitzbergen.
* Astarte compressa—Greenland, Nova Zembla.
* Fusus antiquus—Nova Zembla, Behring's Straits.

A reindeer's horn was found beside these shells. Dr James Geikie states,† that Professor Owen considered it the antler of a young or female reindeer of the existing species. In the paper to which I have already referred,‡ Mr Jack discusses this Croftamie section. He remarks regarding the "stratified clay" in which, he says, the shells were discovered at Croftamie:—"This deposit is interglacial or preglacial—most probably interglacial. It underlies the shelly till" to which I have already alluded, and in which shells were found at a height of 320 feet.

At Kilmaurs, near Kilmarnock, 90 *feet.*—One other example, and I shall conclude these instances of Arctic shells being found at high levels in Scotland. In 1816, remains of the mammoth and reindeer were discovered at Woodhill Quarry, Kilmaurs, near Kilmarnock, 90 feet above the sea, in certain thin beds, underlying what was believed to be till, and resting on sandstone *in situ.* Messrs Young and Craig discussed the subject in 1869 in a paper read before the Geological Society of Glasgow.§ They state that it was reported that marine shells had been found in the same beds which contained the mammoth and reindeer remains; and they announce the discovery in a new pit about half a mile distant from the old Woodhill Quarry, in a sandbed lying under 50 feet of surface drift and boulder clay, of the following Arctic shells:—

Arctic habitat.

* Natica Grœnlandica—Greenland, Norway, Spitzbergen.
* Cyprina Islandica—Russian Lapland, Labrador.
* Astarte sulcata—Russian Nova Zembla, Ochotsk.
* Astarte compressa—Nova Zembla, Greenland.

* "Pro. Royal Phys. Soc.," vol. i. p. 163. Mr James Macfarlane, W.S., was the author of the paper.

† "Great Ice Age," p. 164. ‡ "Trans. Geol. Soc., Glas.," vol. v. p. 24.

§ "Trans." vol. iii. p. 310.

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** Tellina calcarea—Finmark, Greenland, Behring's Straits.
** Pecten Islandicus—Finmark, Nova Zembla, Spitzbergen.

Messrs Young and Craig express surprise that Mr Boyd Dawkins, after referring to the Kilmaurs section, should place the mammoth and reindeer remains in his Postglacial series, or in beds more recent than the boulder clay period; and they consider that the discovery of Arctic shells in sand overlying the bed in which these remains were found, proves that the land here had been submerged for a long time, "since the mammoth and reindeer existed in the preglacial valley of the Carmel at Kilmaurs." Dr James Geikie, however, does not favour this conjecture. He considers * that it is more reasonable to believe that the Kilmaurs deposits belong to one of the latest, if not to the very last, interglacial periods. The boulder clay, which Messrs Young and Craig deemed till, he would relegate to the very termination of the glacial period, as he considers it the result not of the first icesheet (which produced the till), but of the second,—the mammoth, reindeer, and Arctic shells existing during an interglacial period which occurred between the first and second icesheets.

I have now completed the thesis which I undertook to establish. I have shown you that Arctic shells, not now living in British seas, have been discovered at various high levels throughout Scotland, ranging from 90 feet to 510 feet above the sea, and I have given details of these discoveries. At lower levels, such discoveries have been very frequent indeed, and have been confined to no particular locality, but occur so generally as to indicate a wide-spread submergence of Scotland. The following list of more than 50 localities will prove this. Arctic shells have been discovered at the following elevations and localities, viz.:—

Feet above sea.	Locality and Deposit.
63.	At Jordanhill Brickwork, near Glasgow, in clay.[2]
50.	At Ardersier, near Fort George, in blue clay.[1]
45.	At Errol, near Perth, in clay overlying boulder clay.[3]
40.	Around Estuary of South Esk, Montrose, in laminated clay overlying boulder clay.[4]
32.	At Cumbrae College, Isle of Cumbrae, in sand.[2]
30.	At Dalmuir, near Glasgow, in sandy clay overlying boulder clay.[2]
30.	At Crinan Canal, in clay.[2]
30.	At Old Mains, Renfrew, in sand and earth.[2]
30.	At Belhelvie, near Aberdeen, in laminated clay overlying boulder clay.[5]

* "Great Ice Age," p. 174.

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Feet above sea.	Locality and Deposit.
22.	Garnock Water, Kilwinning, in clay overlying boulder clay.[6]
20.	At Carse of Stirling, in blue clay.[19]
15.	At Dumbarton, in clay.[7]
15.	At Kilchattan Tileworks, Bute, in sandy mud.[2]
15.	At East and West Tarbert, in clay.[2]
15.	At Portobello, near Edinburgh, in brick clay.[22]
10.	At Stobcross Docks, Glasgow, in laminated clay.[2]

Arctic shells have likewise been found at the following localities, but I am unable to give the elevations above the sea :—

Windmillcroft Dock, Glasgow, in clay.[18]
Fairfield Dock, Govan, in sand and clay.[2]
Ednie, near Peterhead, in laminated clay.[5]
Lucknow Pit, Ardeer, Ayrshire, in blue sand overlying blue clay.[2]
Paisley, in clay.[2]
Paisley Canal, near Glasgow, in grey clay.[2]
Cartsdyke Dock, Greenock, in laminated clay.[17]
Garvel Park Dock, Greenock, in clay.[2]
Dipple Tileworks, near Girvan, Ayrshire, in grey clay.[2]
Cowdon Glen, Neilston, in clay, sand, &c.[8]
Stevenston, in blue clay.[9]
Tyrie, near Kinghorn, Fife.[10]
Towncroft, near Grangemouth.[8]
Rothesay, Bute, in clay.[8]
Kinness Burn, St Andrews, in clay.[11]
Inchlonaig Islands, Loch Lomond, in grey clay.[7]
Barry, Forfarshire, in clay.[7]
Clashmahew Tileworks, near Stranraer, in brick clay.[7]
Terally Brickworks, near Drummore, Wigtownshire, in clay.[1]
Port Logan cliffs, near Drummore, in clay.[7]
Monreith Tileworks, near Whithorn, Wigtownshire, in clay.[13]
Fort William.[14]
Bo'ness Dock, on surface of red clay.[20]
Orkney Islands (Sanda, Eda, Stronsa, Shapinsha), in boulder clay.[21]

Finally, Arctic shells have been discovered on the sea-coast of Scotland, between tide-marks, at the following places :—

Elie, Fife, in sandy clay.[3]
Fairlie, Ayrshire.[16]
Lochfyne, between Newton and Strachur, in clay.[15]
Ardmarnock, Lochfyne, in sandy grey clay.[23]
Lochgilp, near Lochgilphead, in clay overlying Boulder clay.
Duntroon, Lochgilphead, in clay.[2]

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Tighnabruaich, Kyles of Bute, in sandy clay overlying boulder clay.[2]
Balnakaile Bay, Kyles of Bute, in sandy clay overlying boulder clay.[2]
Ettrick Bay, Kyles of Bute.[2]
Annochie, near Peterhead, in clay.[5]
Invernettie, near Peterhead.[5]

The following are the references to the authors and papers describing the Shell-Beds at the foregoing localities, the most elaborate work of all, however, being the "Monograph of the Post-Tertiary Entomostraca of Scotland," by Messrs Brady, Crosskey & Robertson, printed for the Palæontographical Society of London in 1874, with 16 plates:—

[1] Paper by Mr Wallace, Inverness, cited *supra*, as read 17th Nov. 1881.
[2] See series of papers in Trans. Geol. Soc., Glasgow, by Messrs Crosskey and Robertson on the "Post Tertiary Fossiliferous Beds of Scotland" (1867-1875).
[3] Rev. Thos. Brown, Trans. Royal Soc., Edin., vol. xxiv. p. 617 (1867).
[4] Dr James C. Howden, Trans. Edin. Geol. Soc., vol. i. p. 138 (1868).
[5] Thos. F. Jamieson, Q. J. G. S., London, vol. xxi. p. 196 (1865).
[6] David Robertson, Trans. Geol. Soc., Glasgow, vol. v. p. 292 (1876).
[7] Robertson and Crosskey's "Mon. Post Ter. Ostracoda."
[8] "Great Ice Age," 2d edition, Appendix.
[9] Landsborough, Pro. Geol. Soc., vol. iii. p. 444.
[10] Rev. Dr Fleming, cited by T. F. Jamieson, *ut supra*.
[11] Annals of Nat. Hist., vol. xiv. p. 200 (1864).
[12] Irvine, Mem. Geol. Survey Scot., Expl., vol. iii. p. 23.
[13] J. Craik, Mem. Geol. Survey Scot., Expl. vol. ii. p. 9.
[14] J. G. Jeffrey's Brit. Assoc. Report, 1863, p. 73.
[15] W. Ivison Macadam, Trans. Edinr. Geol. Soc., vol. iv. p. 94 (1881) and 232 (1882).
[16] Mr David Robertson examined this bed.
[17] Bell's "Rocks around Glasgow" (1881) p. 175.
[18] Rev. C. H. Crosskey, Trans. Geol. Soc., Glasgow, vol. ii. p. 115.
[19] James Haswell, Trans. Edin. Geol. Soc., vol. ii. p. 58.
[20] H. M. Cadell, Trans. Edin. Geol. Soc., vol. iv. p. 15.
[21] Messrs Peach and Horne, Q. J. G. S., vol. xxxvi. p. 656.
[22] Hugh Miller, "Edinburgh and its Neighbourhood," p. 83.
[23] Dr Archibald Geikie, Pro. Royal Soc., Edinr., January 1866, reprinted in "Geological Sketches," 1882, p. 164. Dr Geikie gives two parallel shell-bed sections, one on the beach at Nus Fiord in Arctic Norway, where *Tellina proxima*, &c., are found in sandy grey clay, and the other on the beach at Ardmarnock, Lochfyne, where the same shells are likewise found in similar clay.

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LIST of ARCTIC SHELLS mentioned in the foregoing paper discovered at high levels in Scotland, with the Localities and Elevations.

Index to Localities.	Feet above sea level.
Ardersier Manse, near Fort George, Inverness-shire,	50
Arran, Island of, Firth of Clyde,	320
Airdrie, Lanarkshire,	350
Auchleuchries, 20 miles north of Aberdeen,	300
Caithness boulder clay.* Occasionally rising to	200
Chapelhall, near Airdrie, Lanarkshire,	510
Croftamie, Drymen Railway Station, Dumbartonshire,	100
Drummore of Clava, Inverness-shire, 9 miles E. of Inverness,	500
Ellishill, near Peterhead, Aberdeenshire,	120
Gamrie, 9 miles east of Banff,	150
Kilmaurs, near Kilmarnock, Ayrshire,	90
King Edward, near Banff,	150
Loch Lomond, near, in lower valley of River Endrick,	320
Slains Gravel, East coast of Aberdeenshire,	225
Tangy Glen, near Campbeltown, Argyleshire,	130

ARCTIC SHELLS.

* *British species (living).*
** *British species (fossil).*

** Astarte borealis (arctica)—Auchleuchries, Chapelhall, Gamrie, King Edward, Ellishill, Kilmaurs, Arran, Caithness.
* Astarte compressa—Croftamie, Kilmaurs, Arran, Loch Lomond, Caithness.
* Astarte elliptica—Ardersier, Croftamie, Arran, Caithness.
* Astarte sulcata (Scotica)—Gamrie, Kilmaurs, Loch Lomond, Caithness.
* Buccinum undatum—Drummore of Clava, Gamrie, Caithness.
* Cardium edule—Drummore of Clava, Slains, Ellishill, Caithness.
** Cardium Grœnlandicum—King Edward, Caithness.
* Cyprina Islandica—Auchleuchries, Chapelhall, Gamrie, King Edward, Slains, Ellishill, Kilmaurs, Arran, Loch Lomond, Caithness.
** Dentalium entale—King Edward, Caithness.
* Fusus antiquus—Croftamie, Slains, Caithness.
** Fusus carinatus—Slains.
* Fusus contrarius—Slains.

* In the foregoing paper, I cited only those species which are not now living in Britain. The Caithness boulder clay contains almost every Arctic shell found at high levels in Scotland.

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* Lacuna vincta—King Edward.
** Leda lucida—King Edward.
** Leda rostrata (pernula)—Drummore of Clava, Ardersier, Tangy Glen, Arran, Caithness.
* Leda pygmæa—Drummore of Clava, Tangy Glen, Arran, Caithness.
** Leda minuta—Caithness.
* Modiola modiolus—Arran, Gamrie.
* Mya truncata—King Edward, Caithness.
* Mytilus edulis—Drummore of Clava, Ellishill, Caithness.
* Natica pusilla (Grœnlandica)—Drummore of Clava, King Edward, Kilmaurs, Caithness.
** Natica clausa (affinis)—Gamrie, Caithness.
** Natica pallida—King Edward, Caithness.
** Pecten Grœnlandicus—Tangy Glen.
** Pecten Islandicus—Ellishill, Kilmaurs, Arran, Caithness.
** Pleurotoma turricula—Drummore of Clava.
* Purpura lapillus—Auchleuchries, Slains, Caithness.
** Rynchonella psittacea—Caithness.
** Saxicava rugosa (arctica)—Ellishill, Caithness.
** Scalaria Grœnlandica—King Edward.
** Tellina Grœnlandica (Balthica)—Drummore of Clava, Slains, King Edward, Arran, Caithness.
** Tellina calcarea (proxima)—Chapelhall, Ardersier, Airdrie, Gamrie, King Edward, Kilmaurs, Caithness.
** Trophon clathratus—Drummore of Clava, King Edward, Loch Lomond, Caithness.
* Trophon truncatus—King Edward, Caithness.

It will be observed that of the above thirty-four species of Arctic shells, eighteen (or more than one-half) are not now living in British seas, but are found living only in Arctic regions.

Note on Arctic Shell-Bed Map of Scotland.

On this map I have indicated all the localities known to me where Arctic shells have been discovered in Scotland, with the elevations above the sea where these are mentioned by the discoverers in describing the shell-beds. I also represent upon this map the submergence of 500 feet which Scotland underwent, as evidenced by the discovery of Arctic shells at that level.

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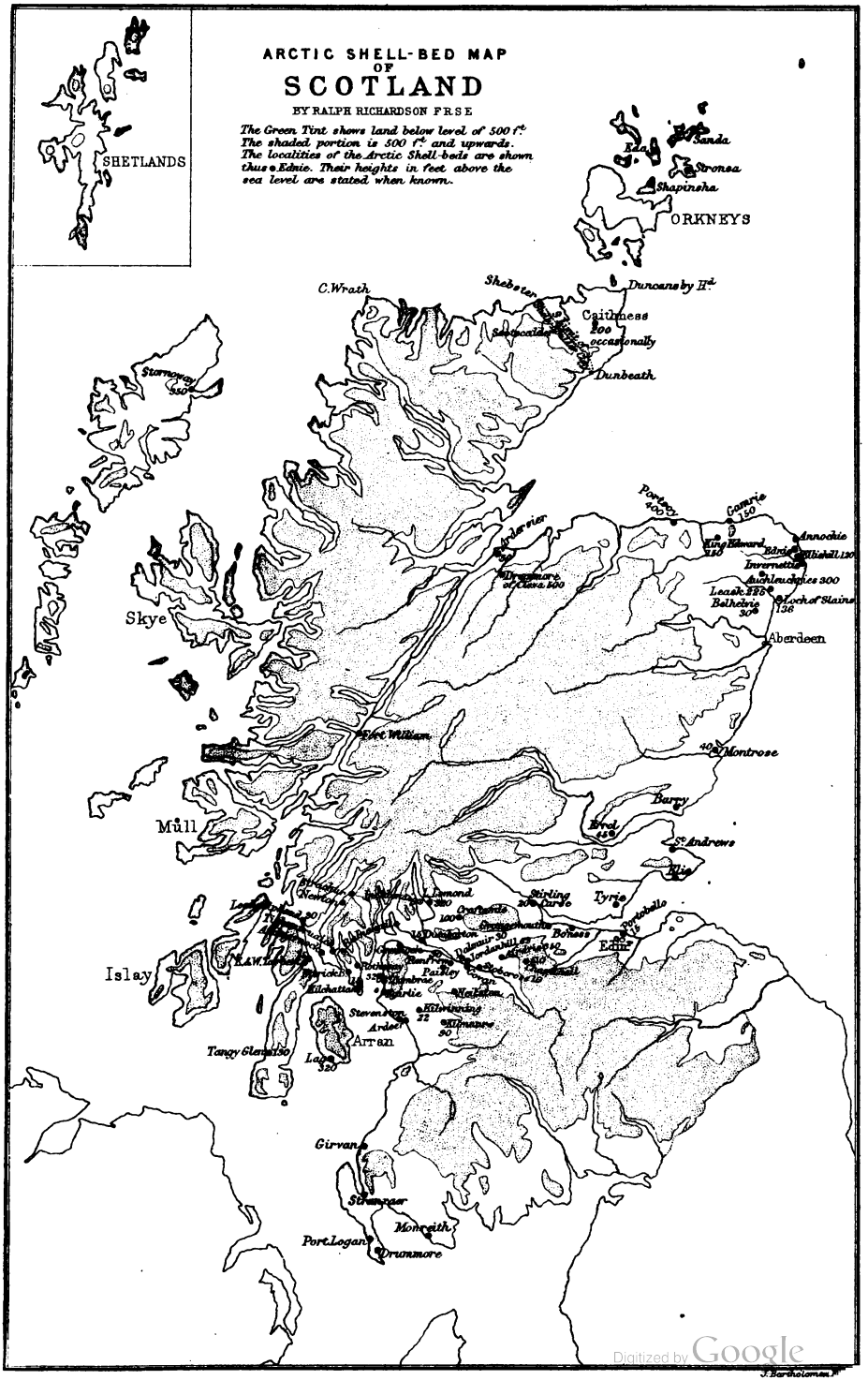
ARCTIC SHELL-BED MAP
OF
SCOTLAND
BY RALPH RICHARDSON F.R.S.E.
The Green Tint shows land below level of 500 ft.
The shaded portion is 500 ft. and upwards.
The localities of the Arctic Shell-beds are shown thus ● Edrie. Their heights in feet above the sea level are stated when known.
SHETLANDS
ORKNEYS
Sanda
Eday
Stronsa
Shapinsha
C. Wrath
Sheboster
Duncansby Hd.
Caithness
occasionally
Dunbeath
Stornoway
Skye
Portsoy
Cairnie
Annochie
Inverness
Aberdeen
Fort William
Montrose
Barry
St. Andrews
Elie
Tyrie
Edinr.
Mull
Islay
Arran
Girvan
Stranraer
Monreith
Port Logan
Drummore
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J. Bartholomew

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XIV.—*Notes on the Geology of Deeside, near Ballater.* By Wm. Hamilton Bell.

(Read 20th April 1882.)

In August 1880, having been led to choose Ballater as summer quarters, I found that the surrounding district was one possessing very interesting geological features. On studying my geological map, I found that it contained the serpentine formation, and not having met with it before elsewhere, I took it up as one of my studies, not from its being of very great interest in itself from the authorities I had then read on the subject, but from its novelty, which has its pleasure and profit when no other special formation is to be found on the spot.

In Juke's and Geikie's Manual, serpentine is described as "a rock intimately associated with altered limestone, and is itself, probably, in many cases a further stage of metamorphism of magnesian limestone." "But it may be the result of metamorphism of augitic, hornblende, or olivine bearing rocks. It is compact, dull, usually of some shade of dirty green, with a splintery fracture and easily scratched. It occurs sometimes in small veins, layers associated with limestones, and sometimes in large masses, and forms ranges of hills." The formula according to the same authority appears to be 44·14 of silica, 42·97 of magnesia, and 12·89 of water. In the section attached to Knipe's map of the general formation of the earth's crust, I see that the serpentine is placed next to the gneiss and mica.

I have found no special work on serpentine, but have consulted De la Beche, Bonney, and others who have treated of it; and I have derived the most useful information on the subject from the papers of Professor Heddle in the "Royal Society's Transactions," where he deals with the mineralogy of Scotland. It has been more prominently dealt with in foreign journals, where I suppose the formation is more fully met with than in this country, but I do not enter into any dissertation here, as my object is more to note what I found in the locality than what it may be elsewhere.

The serpentine is found *en masse* on the Coyle, which is a hill divided into three summits. It is on the property of the Prince of Wales at Birkhall, about 4 miles from Ballater. Between the Coyle and Abergeldie, the residence of the Prince, the march line crosses the north-west peak. It rises on the north side of the River Muick; and on the opposite side the rock is gneiss, which formation continues up to Loch Muick, (out of which this stream

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flows), and extends down towards Ballater, to the Braichley Burn, which sharply divides it from the granite. On the west side of the Coyle, towards Lochnagar, granite is the formation; but the Coyle is almost entirely serpentine. I paid numerous visits to the hill, and at first was disappointed at not finding more of what I then could distinguish as serpentine, and had to content myself with small success. I found, however, some fine specimens of the best kind, and on my return to town I entered more fully into the study of the subject. I also procured some large specimens from Unst in Shetland, and I then remembered the peculiar weathering of the rocks, without at the time knowing that it was serpentine, so it was with increased zest that on my return to Ballater in 1881 I resumed my researches there.

In then prosecuting my inquiries I found that in Scotland the serpentine is mostly met with in Shetland; At Portsoy in Banffshire, The Coyle; In Ayrshire, and at Colmonell, Girvan, and elsewhere in that neighbourhood. I had gained much information on the geology of the district during the previous year, from Alexander Shivas, the police constable at Ballater, who I found to be a man, that seems to combine with his duties of looking after the waifs and strays of the population, the happy knack of keeping his eyes open to the stray geological formation of the neighbourhood as he passes along. In my talks with him in 1881 I found that Professor Heddle had gone over the whole district, and the Rev. Mr Mickie, the Established Church minister of Dinnet, was well acquainted with the Coyle. I wrote to Professor Heddle, and he most kindly sent me the third chapter of his report to the Royal Society on the mineralogy of Scotland. In this he deals fully with the serpentine beds I was in pursuit of, and in following his remarks upon my geological map, I found they both agreed; that from Portsoy the serpentine bed can be traced to the Bück of Cabrach in Banff, from whence they trifurcate. One bed passing to the south-west loses itself in the serpentine marble of Glentilt; another striking due south is seen on the Kindy, Morven, Culbleen, passes on to the Coyle, is again seen in the cliffs of the Canlochan of Glen Isla, and is last seen at Kingoldrum and Lintrathen near Catlaw Hill in Forfarshire; while the third, running east by Chapeltown, Insch, Oyne near Benochie, Prenmay, Barrahill, Beauly, and Belhelvie, passes into the German Ocean 5 miles north of Aberdeen, as the Schiller Spar of the Black Dog Rock. It is instructive to note how it thus breaks out suddenly at different places, and then disappears. I passed through the Royal Deer Forest of Balmoral, from Inchbobart on Loch Muick, to Abergeldie, at the very foot of the Coyle, and not a vestige of the appearance of the rock was to be seen except on the hill itself.

On renewing my researches last summer (1881), and being

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now somewhat acquainted with the peculiar weathering of the rock, I had no difficulty in recognising at once the full extent of the formation. The hills rise to 1900 feet above the level of the sea, and about 1200 feet above the Muick.

On ascending the north-east shoulder, I found some beds of red porphyry and granite *in situ*, with many boulders of granite, but no serpentine, until about 200 feet from the summit. I found there, that the hill was one amorphous mass of serpentine. I now recognised the peculiar weathering of the Shetland rock, and wondered I had not been struck with it the previous year, for having once ascertained it was serpentine, I had no more difficulty in recognising it wherever I met it. The serpentine on this shoulder is of a coarse greenish-grey colour outside, but where broken up is of a dark greenish hue, very tough, but splintery, with continual veins of steatite running through it. The south-west, and highest summit, is also one mass of serpentine of the same amorphous nature, but I found some very fine veins of what is noble serpentine, much harder, and which takes a fairish polish. Indeed I have had some shirt ornaments, &c., and plaid brooches made from it, and although the polish is not so fine as agate and other minerals, yet they keep me in memory of the pleasure I had in their capture.

The south-west summit is so peculiar that I think it right to take a little more note of it. It rises into a very abrupt cone of about 200 feet above the body of the hill, and is so exceedingly like a volcanic cone of pure serpentine, that I at first thought it had been the crater of a volcano. Almost all the authorities hold that in most instances serpentine is an igneous eruptive rock, but generally so in intrusive veins, but here it seems to have been forced out from this cone, and spread over the whole hill, as is seen in so many cases where basalt, greenstone, &c., have been ejected in lava-like streams. This is especially the case on the north-west and south-west summits, but on the centre or lowest summit the same appearance is not so visible. I also found on the south-west hill some good specimens of asbestos. I find in Rutley's Mineralogy a remark "that serpentine is found in a fibrous state resembling asbestos, and then is known as chrysolite," but I produce a large specimen found here, which is pure asbestos. Actynolite in talc, as well as chrysolite and malacolite, is also to be found here.

The only other matter I would refer to in connection with the serpentine on these hills is, that having heard it stated that the soil of that formation is generally barren, I found here, that over the whole hill the grass was fine and very green, and almost no heather where the serpentine was *in situ*; almost no grouse found; in fact, the pasture, to the extent of 1000 acres I should say, is let for sheep grazing, while the hills in the imme-

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diate neighbourhood are granite, and the soil cold and sour. Mr Mickie also noticed the same peculiarity in the Hill of Morven 8 miles away, where serpentine is also found, and states that there the very same characteristic obtains as I have here noted, and that at 2 miles distance you can tell where you will find serpentine and where granite, and be guided to the junction of the two rocks within a few yards.

Leaving the serpentine, I would now turn eastward and take notice of a district mentioned by Mr Michie in a geological, archæological, and historical work on the district of Loch Kinnord. He states that during the tertiary period, the Muir of Dinnet (4 miles east of Ballater) and district of Kinnord formed the largest of the whole series of lakes that occupied the valley of the Dee from the Linn of Dee to Aboyne. "It was produced by a rocky barrier, stretched across the valley of the Dee above Aboyne, and the lake, thus formed, terminated in a fine bay, the shores of which swept round behind the farm of Ballaterich, and away northward with many a headland and creek into the district of Cromar." The whole of this district has evidently been a lake, at one time occupying an area of at least 7 miles from north to south, and 5 from west to east. It is bounded by Morven (2800 feet high) on the west, the Hill of Sockhaugh, near Logie Colston, on the north, Mortlich on the east, and the Dee on the south. There are remains of this lake still visible in the lochs of Kinnord and Davan, of which Mr Michie has given a most interesting account.

These lochs are very beautiful, although surrounded by peat mosses, and I may mention that I found large quantities of a very old decayed white peat, which I was led to look for there, from two articles published in the *Aberdeen Free Press* in August 1880. It was there spoken of as a substance which might take the place of the German kiesselghur so much used in the manufacture of dynamite, and for this purpose parties were in treaty with the proprietor.*

Leaving Loch Kinnord and proceeding west from Bogangore, by what was the old road to Ballater, at the foot of Culbleen Hill, at about 200 feet above the bed of the Dee, I came upon a series of heather-covered moraine-like mounds, continuing through the moor for fully 2 miles. The road cuts through these mounds in many places, so that the interiors are quite exposed. These present the appearance of masses of water-worn gravel, mixed in the most pell mell confusion, the boulders being often of very large size; but I observed no striæ, nor any of the blue tenacious clay of the Till, which it so much resembled. These moraine-like mounds are innumerable, and are scattered all over the moor to the

* See Paper by W. Ivison Macadam, page 207.

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extent of 300 or 400 yards on each side of the road and up to the foot of the hills. They are more numerous and larger at the outlets of two streams which flow from Morven, 2 miles back to the north, viz., the Glen Colston and Tullich Burns, the height of the mounds often reaching 30 or 40 feet. I may here mention in reference to these mounds that I have met with the same in two other localities—one at the foot of the Hill Benchonzie (3000 feet high), 7 miles north of Crieff. At the foot of the last summit of that hill, these mounds are scattered about in all directions as far as Loch Turrit, and continue, after leaving that loch, to the steep descent of the River Turrit. They are even seen occasionally until that river reaches the level ground before it enters the Earn at Crieff. The other locality is on the road that passes the foot of Ben Cruachan on the road between Dalmally and Inveraray. They are quite similar in appearance to those above mentioned; but my attention was not turned to them at the time, and it was only on meeting them here that they recurred to my recollection.

On approaching Ballater from the east after leaving these moraines we come to the Pass of Ballater, which lies between the Hill Craigandarroch and another hill which seems to have once formed part of it. Craigandarroch is about 500 feet high above the plain, in which Ballater is seen lying at its foot. It is of red granite, and of very much the same formation as the hill on the other side of the pass. On the side of Craigandarroch the slope is very steep, but on the other side it is more so, and the granite is tossed about in the utmost confusion, the masses often consisting of blocks of hundreds of tons. It looks as if the two hills had been once united, but torn asunder by some mighty convulsion. I notice this, because while Craigandarroch, which presents the appearance of a huge grave mound, is thus torn asunder, there are two similar hills about 3 or 4 miles further up the Dee, on its opposite side. The one is called Craig Yourie, and is fully 600 feet high—it is of granite also, and entirely separate from the adjoining ground like Craigandarroch; while the other, at the foot of which Abergeldie lies, is of the same appearance to the north, but continues its junction with the hills behind it, and resembles what I think Craigandarroch might have been before its disjunction with the adjoining hill at the pass. I mention this as these hills have often puzzled me as to their formation.

At the west end of the Pass of Ballater, at Abergairn, and immediately behind the Free Church manse of Ballater, the Hill of Pronich rises to the north to a height of 1500 feet. In this immediate neighbourhood, there is a fine lode of lead or galena. The rock in which the lead is found is a dark brown ferruginous gneiss, like charred wood. A great deal of pure

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white quartz, in large boulders, and *in situ*, is close to the lead, but it is in the gneiss and the fluor spar, purple and green, that the mine has been sunk. The lead and fluor spar are associated with a very fine zinc blende in large quantities also.

The proprietor, the Marquis of Huntly, for some years conducted a series of explorations here, with the view of developing these minerals. They were first directed by Mr Bett, an eminent English mining engineer and geologist, and afterwards by Mr Michie of Dinnet, and I believe, a company is being treated with, with the object of taking a lease of the mines. In the meantime, however, operations are suspended. An exposure of this lode of lead was made on the banks of the Dee 2 miles further west, at the breaking up of the ice in 1881, but not to any extent; and there is a story current that Mr Farquharson of Monaltrie many years ago got enough silver out of lead found a mile east of this to make buttons for his chieftain jacket and a snuff-box. The zinc found is said to be the purest of any found in the country.

I come now to the last of my researches in this neighbourhood. Proceeding up the River Gairn, which rises at the foot of Ben Avon, and enters the Dee about 1½ mile from Ballater, the hills on the east side are granite, but on the west gneiss. I was struck with the numerous old limekilns I met with, and about 5 miles up I came upon a large limestone quarry, called Dalnabo, at the back of the Hill "Gailleigh." I found idocrase in large abundance in the quarry, and cinammon stone; and Professor Heddle, in his before-mentioned report, gives the names of twenty-three minerals found on the Gairn, some of them very rare; in fact, more minerals are found here than in any other locality in his Report.

From what I had heard from my friend the policeman, I proceeded up the Gairn to Gairn Shiels shooting-lodge, and about a quarter of a mile from Rinloan Inn, and where the river comes sharply in from the north, I found a vein of red trachyte. I understand that this trachyte runs through the Gaelligh Hill in a south-east direction, and appears again in the south at about the same distance from Kylochreich Inn on the road from Ballater to Balmoral, but I did not follow it over the hill. It crops out, however, in several places on the above trend, and is sometimes seen with other veins of trachyte, blue and white in colour.

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XV.—*On the Analysis of a Sample of a White Deposit from the Peat of Aberdeenshire.* By W. IVISON MACADAM, F.C.S., F.I.C., Lecturer on Chemistry and Analytical Chemist, Edinburgh, *Honorary Secretary to the Society.*

Mr William Hamilton Bell in his paper on "The Geology of the Deeside near Ballater,"* says:—"These lochs are very beautiful although surrounded by peat mosses, and I may mention that I found large quantities of a very old decayed white peat, which I was led to look for there, from two articles published in the *Aberdeen Free Press* in August 1880. It was there spoken of as a substance which might take the place of the German *Kieselguhr*, so much used in the manufacture of dynamite, and for the purchase of which, for that purpose, parties were in treaty with the proprietor."

Mr Bell placed samples of the "white peat" at my disposal, and the results of the investigation I now beg to lay before the Society.

The *Aberdeen Free Press*, in the article quoted by Mr Bell, states that in the basin of Loch Kinnord and in the Ordie Moss a whitish earthy substance is found lying alongside of the peat in the "bottoms" from which the latter is cut for fuel. The article further states that the Rev. Mr Davidson, minister of Coldstone, had examined the "white peat" microscopically, and had found the material to be composed of diatoms.

I have subjected the material to an exhaustive chemical and microscopic analysis, with the following results :—

The "white peat" is a grey-white porous, very light, fibrous mass. On treating the peat with ether and evaporating the solution a fine green coloured body is obtained, which on further analysis is proved to be chlorophyl, the substance which gives the green colour to the leaves of plants. The presence of this chlorophyl goes far to prove the vegetable origin of at least a part of the peat. On the application of heat, the peat chars and loses 25·29 per cent. of its weight. The microscopic examination of this organic portion shows it to be made up of cellulose and ligneous matters derived from vegetable sources. The remaining 65·55 per cent., after allowing for 7·45 per cent. of moisture, is made up of inorganic material, principally composed of the flinty siliceous skeletons of diatoms. The material under the microscope presents a most beautiful field, the diatoms being both numerous and various, and interspersed with particles of silica and mineral matter of undoubted

* "Trans. Geol. Soc. Edin.," vol. iv. part ii. p. 204.

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metamorphic origin. The chemical results obtained from the analysis are given in Table A.

TABLE A.—ANALYSIS OF WHITE SUBSTANCE FROM DINNET MOSS, ABERDEENSHIRE.

Moisture,	7·450
Organic matter soluble in ether (chlorophyl, &c.),	1·708
Organic matter insoluble in ether (cellulose, lignose, &c.),	25·290
Inorganic constituents,	65·552
	100·000

The organic portion was also analysed for its ultimate constituents, and gave the following results :—

TABLE B.—ULTIMATE ANALYSIS OF ORGANIC PORTION.

Carbon,	44·243
Hydrogen,	6·374
Oxygen,	49·383
	100·000

These figures would give a formula almost agreeing with $C_6H_{10}O_5$, or the proportions in which the elements are present in cellulose—the exact proportions necessary for the formula being—

Carbon,	44·444
Hydrogen,	6·173
Oxygen,	49·383
	100·000

The results obtained when calculated to the proportions present in the original body give—

TABLE C.—ANALYSIS OF WHITE SUBSTANCE.

Organic constituents insoluble in ether—		
Carbon,	11·189	
Hydrogen,	1·612	
Oxygen,	12·489	
		25·290
Organic constituents soluble in ether,		1·708
Inorganic constituents,		65·552
Moisture,		7·450
		100·000

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The inorganic constituents were also subjected to analysis, with the following results :—

TABLE D.—ANALYSIS OF THE ASH.

I. *Soluble in Water.*

Calcic oxide,	1·216	
Magnesic „	0·504	
Potassic „	0·313	
Sodic „	0·115	
Sulphuric anhydride,	0·753	
Chlorine,	trace	
		2·901

II. *Soluble in Hydric Chloride.*

Ferric oxide,	5·504	
Aluminic „	2·101	
Calcic „	2·939	
Magnesic „	0·635	
Alkalies, &c.,	0·271	
Phosphoric anhydride,	trace	
Soluble silica,	1·125	
		12·575

III. *Silicates decomposed by Hydric Fluoride.*

Ferric oxide,	0·232	
Aluminic „	1·106	
Calcic „	0·184	
Magnesic „ &c.,	0·042	
		1·564
Silica,		82·960
		100·000

These results show that the "white peat" is partly of vegetable origin, and partly composed of animal remains.

The Rev. George Davidson informs me that his frequent dredgings in the deeper parts of Loch Kinnord show a deposit of nearly pure diatoms, and that it is only at the sides where the water plants (Phragmites communis, Equisetum limosum, Equisetum fluviatile, and various species of Sphaguum) have obtained a footing that the white substance is obtained. It thus appears that the vegetable matter is the remains of those plants which found a suitable soil in the diatomaceous deposit where such existed in the shallower parts of the loch. The white

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deposit is overlaid by ordinary brown peat, from which, in the moist condition, it can hardly be distinguished, and which, at the Black Moss deposit, was from 10 feet to 14 feet in thickness. This upper peat has been removed for fuel, but the lower diatomaceous layer remains, as it is useless as a heating agent.

Mr G. H. Kinahan, M.R.I.A.,* says that a typical lowland or red bog gives four varieties of peat—1st, a clearing of more or less living organic matter of from 2 feet to 6 feet deep; 2nd, white turf; 3rd, brown turf; and 4th, black or stone turf. Referring to the white turf, Mr Kinahan says that it is a nearly pure organic substance, very light when dry, burns readily, giving, however, very little heat, and leaving little or no ash. Another variety is also mentioned which is stated to be somewhat like soap in consistence when freshly cut, but dries readily, becoming disintegrated. When half dried and then stacked it forms a good fuel, giving much heat and light. The colour of this variety is a pale green. In the same paper Mr Kinahan notes that the lower down the turf is obtained, the higher the ash or mineral matter present. The Aberdeenshire variety partakes partly of the characters of both these examples, but differs materially from either. It possesses the chlorophyl of the latter specimen, with the bad burning and heating properties of the first.

Since writing the above paper I have been in communication with the Rev. George Davidson, minister of Logie Coldstone, Dinnet, Aberdeenshire, and whose microscopical labours are so well known. He has kindly sent additional information regarding the deposits, and after much trouble and time also furnished a list of the Diatomaceæ he has discovered in the Kinnord deposit. This list is appended to the paper, and will furnish, I hope, a permanent record of Mr Davidson's labours in this special field of research. In the communication received from Mr Davidson he says: "The deposit in Loch Kinnord is of considerable extent, especially towards the west end, where the Burn of Culbleen flows into the lake, richly charged with silica from the friable granite of that hill. What had once formed part of the same loch and is now known as the 'Black Moss' (about 1½ mile to the north-east), contains a still larger deposit. Last year Lord Aberdeen, to whom it belongs, had it carefully examined by sinking shafts in many places, and it was found that the guhr here amounts to rather more than 800,000 cubic yards. When thoroughly dried it takes 6 cubic yards of the raw material to form a ton."

* "Geology of Ireland," chapter xvi., and "Journal of Science," No. xliii., July 1874.

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"It is interesting to note that it is only on the west side of Loch Kinnord that the guhr is found in any quantity, as this point is nearest to the silex-charged feeder. Another lake, Loch Dawin, close to both the others, is fed by a large stream which takes its rise about 5 miles distant on a hornblende hill, and in it scarcely any diatoms, either fossil or recent, are to be found."

The material is now largely employed instead of "Kieselguhr" in the manufacture of dynamite, a purpose for which, from its open porous nature, it is admirably fitted. Other uses, such as the manufacture of ultramarine, polishing substances, and other bodies where a finely-divided siliceous base is required, have, to some extent, utilized the deposits, but many other uses will undoubtedly be found for this new substance. It is probable that a thorough search will reveal in other localities like deposits.

As the substance is being so largely substituted for "Kieselguhr," it may be of interest to note the analyses of various deposits as given by Professor Bonn in his "Diatomées des Alpes et du Jura."

ANALYSE DE KIESELGUHR DE FRANZENSBAD, PAR ROB. HOFFMAN (1863).

Silice,	77·000
Alcalis,	0·401
Magnesie,	0·049
Chaux,	traces
Oxyde de fer et Alumine,	0·910
Acide phosphorique,	0·190
Eau,	6·000
Perte (en partie organique),	15·450
	100·000

ANALYSE DU KIESELGUHR DU HANOVRE, PAR M. ZIEGLER (1862).

Silice,	84·15
Alumine,	1·40
Oxyde de fer,	0·70
Manganèse,	traces
Carbonate de chaux,	1·75
Carbonate de magnesie,	1·10
Potasse,	0·25
Eau,	10·40
Perte,	0·25
	100·00

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ANAL. D'UN KEISEL. DE HOLLANDE, PAR L. LOSSIER (GENEVE, 1878).

Silice, ...	84·37
Phosphate de fer et d'Alumine, .	2·55
Chaux, ...	0·35
Magnesie, ...	0·07
Alcalis, ...	0·60
Eau (et matieres organiques), . .	12·68
	100·62

It will thus be seen that the Kinnord deposit, whilst not unlike in the ingredients found, differs greatly in the proportions present.

I take this opportunity of acknowledging my gratitude to Mr Davidson for the trouble and labour my requests have caused him. Also to the Rev. J. G. Michie, Manse of Dinnet, to whom I am greatly indebted for much valuable information. To both these gentlemen my thanks are due for reading and correcting proof sheets. The subject is being further investigated.

LIST of DIATOMACEÆ found in Loch Kinnord Kieselguhr, by the Rev. GEORGE DAVIDSON, Minister of Logie-Coldstone, Dinnet, Aberdeenshire.

Epithemia turgida, Ktz.
„ gibba, Ktz.
„ sorex, Ktz.
„ Zebra, Ehr.
5 „ ocellata, Ktz.
„ gibberula, Ktz.
„ Alpestris, Ktz.
„ ventricosa, Ktz.
„ Hyndmanii, Smith.
10 „ granulata, Ktz.
„ proboscidea, Ktz.
„ globifera, Heiberg.
Eunotia Arcus, var. incisa, Ehr.
„ uncinata, Ehr.
15 „ gracilis, Sm.
„ major, Sm.
„ impressa, var. minor, Grunow.
„ Formica.

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Eunotia nodosa, Ehr.
20 „ pectinalis, Dillw.
„ undulata, Sm.
„ tetraodon, Ehr.
„ ventricosa.
„ bigibba, Greg.
25 „ Diadema, Ehr.
„ Camelus, Ehr.
„ monodon, Ehr.
„ Faba, Ehr.
„ lunaris, Breb.
30 „ triodon, Ehr.
„ Sp. (?)
Cymbella Ehrenbergii, Ktz.
„ cuspidata, Ktz.
„ Scotica.
35 „ hercynica, Schmidt Atlas, ix. 30, 31.
„ Pisciculus, Greg.
„ turgida, Greg.
„ naviculiformis, Amd.
„ Sp. (?) Atlas, ix. 56.
40 „ obtusiuscula, Ktz.
„ angustata, Grun.
„ Norwegica, Grun.
Cymbella acutiuscula, Grun.
„ æqualis, Sm.
45 „ (Navicula) Cesatii (Rhab.).
„ anglica, Lagerst.
Amphora ovalis, Ktz.
„ lineata.
Cocconeis Placentula, Ehr.
50 „ Helvetica, Brun.
Achnanthidium flexellum, Breb.
„ lanceolatum, Breb.
„ Jackii (?)
Cyclotella operculata, Ktz.
55 „ rotula, Ktz.
„ Kutzingiana, Thw.
„ papillosa, O'Meara.
„ antiqua, Sm.
Surirella nobilis, Sm.
60 „ splendida, Ktz.
„ linearis, Sm.
„ tenera, Greg.
„ constricta, Ehr.
„ Craticula, Ehr.
65 Tryblionella angustata, Sm.

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Cymatopleura apiculata, Pritch.
„ elliptica, Breb.
Nitzschia angustata, Grun.
„ Denticula, Grun.
70 „ linearis, Sm.
„ Sigmoidea, Sm.
„ parvula, Sm.
Navicula divergens and vars., Sm.
„ acuta, Kg.
75 „ nodosa, Ehr.
„ stauroptera, Grun.
„ gibba, Ktz.
„ viridula, Ehr.
„ firma, Ktz. and Grun.
80 „ hebes, Ralp.
„ mesotyla, Ehr.
„ lævissima, Grun.
„ Sp. (?), Atlas of Diat., 44, 51.
„ nobilis, Ktz.
85 „ follis, Ehr.
„ Rhomboides, Ehr.
„ Amphioxys, Ehr.
„ major, Ktz.
„ Mormonorum, Atlas, 44, 24.
90 „ dicephala, Ehr.
„ var. Stauroneiformis.
„ Brebissonii, Rabh.
„ viridula, var. major.
„ rupestris, Grun.
95 „ Iridis, Ehr.
„ viridis, Ktz.
„ interrupta, Ktz.
„ cuspidata, Ktz.
„ angustata, Sm.
100 „ ovalis, Sm.
„ Americana, Ehr.
„ cocconeiformis, Greg.
„ Sorians, Kg.
„ affinis, Ehr.
105 „ borealis, Ehr.
„ limosa, Grun.
„ radiosa, Rabh.
„ cardinalis, Ehr.
„ divergens, var. Mullensis, Greg.
110 „ semicruciata, Ehr.
„ gracillima, Pritch.
„ polyonca, Breb.

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Navicula amphigomphus, var., Atlas, 49, 31.
„ fulva, Ehr.
115 „ punctata, Ehr.
„ Sp. (?), Atlas, 44, 51.
„ Bacillum, Ehr.
„ Stauroptera, var., Grun.
„ Sp. (?), Atlas, 43, 25.
120 „ pygmœa, Ktz.
„ Scutelloides, Sm.
„ tumida, Sm.
„ acrosphœria, Breb.
„ Hitchcockii, Ehr.
125 „ Braunii, Grun.
„ inflata, Ktz.
„ leptogongyla, Ehr.
„ Sp. (?), Atlas, 45, 28.
„ Sphœrophora, Ktz.
130 „ termitina, Schmidt.
„ commutata, Schmidt.
„ crassinervia, Breb.
„ exilis, Grun.
„ rhyncocephala, Ktz.
135 „ lacustris, var., B. Greg.
„ oculata, Breb.
„ mesolepta, Ehr.
„ amphirhynchus, Ehr.
„ Zellensis, Grun.
140 „ Serians, var. minor.
„ hemiptera, Ktz.
„ undulata, Greg.
„ nodulosa, Grun.
„ Stomatophora, Grun.
145 „ rhombica, Greg.
Stauroneis Phœnicenteron, Ehr.
„ anceps, Ehr.
„ dubia, Greg.
„ acuta, Sm.
150 „ linearis, Ehr.
Pleurosigma attenuatum, Sm.
„ lacustre, Sm.
„ Spencerii, Sm.
Synedra ulna, Ehr.
155 „ biceps, Kg.
„ capitata, Ehr.
„ lunaris, Ehr.
„ radians, Kg.
„ linearis, Sm.

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160 Synedra longissima, Sm.
„ acus, var. tenuissima, Kg.
Cocconema lanceolatum, Ehr.
„ cymbiforme, Ehr.
„ cistula, Hemp.
165 „ parvum, Sm.
„ Helveticum, Grun.
Gomphonema acuminatum, Ehr.
„ insigne, Greg.
„ dichotomum, Ktz.
170 „ constrictum, Ehr.
„ subtile, Ehr.
„ vibrio, Ehr.
„ Hebridense, Greg.
„ Brebissonii, Grun.
175 „ intricatum, Kg.
„ turris, Ehr.
„ geminatum, Ag.
„ Cygnus, Ehr.
„ tenellum, Kg.
180 „ elongatum, Grun.
Fragilaria capucina, Desm.
„ lapponica, Grun.
„ virescens, Ralfs.
„ var. exigua, Grun.
185 „ construens, Grun.
„ undata, Sm.
Tabellaria fenestrata, Lyngb
Stenopterobia anceps, Grun.
Encyonema gracile, Rab.
190 „ Lunula, Grun.
„ cæspitosum, Kg.
Denticula tenuis, Kg.
„ inflata, Sm.
Tetracyclus lacustris, Ralfs.
195 Melosira crenulata, Thw.
Stephanodiscus minutulus, Grun.
Campylodiscus noricus, Ehr.
Odontidium mutabile, Sm.
Mastogloia Grevillei, Sm.
200 Ceratoneis Arcus, Kg.

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XVI.—*On some Marine Beds underlying the Gilmerton Limestone.* By JOHN HENDERSON.

(Read 4th May 1882.)

The Calciferous Sandstone series of Mid-Lothian, although deriving the name from a number of limestone beds intercalated with the sandstones and shales of that extensive division of the Carboniferous formation, has always been considered remarkable for the absence of true marine fauna. With the exception of one or two thin beds in the Wardie shales, containing species of *Orthoceras, Corrularia, Bellerophon*, &c., no other marine beds have been recorded as occurring in the Calciferous sandstones of this district. Not even in those beds which were examined principally by myself, and the fossils described and figured by Mr R. Etheridge, jun., in the *Journal of the Geological Society* for February 1878, do we find a vestige of true marine Brachiopoda, such as *Productus, Orthis, Spirifer*, &c., and which are so abundant in the Carboniferous Limestone or Edge Coal series of Mid-Lothian—the division of the Carboniferous that lies above the Calciferous Sandstone series. The Gilmerton limestone which forms the base of the Edge Coal series contains abundance of these marine Brachiopoda. The supposed absence of true marine Brachiopoda in the Calciferous Sandstones of Mid-Lothian was all the more remarkable from the fact that in Fife abundance of marine beds occur in the Calciferous Sandstone series. J. W. Kirby, Esq., in a paper published in the *Quarterly Journal of the Geological Society* for November 1880, describes a series of marine zones that occur in the Calciferous Sandstones of Fife, in which, beginning at the top of the series and passing down through a thickness of 4000 feet, he enumerates eighteen zones of marine fossils, most of them containing the remains of true marine Brachiopoda.

In the present notice I have to record the existence, in the Calciferous Sandstone series of Mid-Lothian, between 300 and 400 feet below the Gilmerton limestone at Stenhouse Mills, 3 miles south of Edinburgh, of several beds containing the remains of true marine Brachiopoda. The section containing these beds is exposed in the Burdiehouse Burn for about 300 yards above the mill at Stenhouse. The Gilmerton limestone, which is exposed in a long line of quarries to the west of the village of Gilmerton, has an easterly dip till it enters the estate of Moredun, at the north end of the quarries, where it strikes west, with a northerly dip, crossing the Burdiehouse Burn about a

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hundred yards above Stenhouse Mill. This limestone, the base of the Carboniferous Limestone series, is well exposed through its whole thickness in the bed of the burn.

The base is encrinital. It is underlayed by about 30 feet of black shale, which should be considered the top of the Calciferous Sandstone series; beneath the black shale comes a considerable thickness of bedded sandstone; these are again underlayed by black and grey shales, and so on, shales and sandstones alternating down through a thickness of 300 feet vertical below the Gilmerton limestone, where the first bed of limestone with marine fossils occurs. It is of a shaley nature, and may be about 7 feet thick. Three very distinct forms of marine Brachiopoda, viz., *Productus longispina*, *P. semireticulatus*, and *Orthis Mitchelini*, are present.

The second bed occurs about 8 feet lower down, and is about 8 inches thick. It contains abundance of *Orthis Mitchelini*, besides other fossils. It weathers into flat rounded nodules and a brownish dust, quite unlike any other limestone I am acquainted with in the Carboniferous rock. Another limestone, several feet thick, and mostly made up of encrinites, occurs about 50 feet below those already described; and further up the burn, where the lowest beds in the section are to be seen, there are evidences of another marine limestone. It will be seen that there are in the Calciferous Sandstone series of Mid-Lothian marine beds comparable with those described as occurring in the Calciferous series in Fife, and I have no doubt further search will reveal others, bringing the contemporaneous series of Fife and Mid-Lothian into still closer relationship.

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XVII.—*Note on the Occurrence of the Remains of Decapod Crustaceans in the Wardie Shales.* By THOMAS STOCK, Natural History Department, Museum of Science and Art, Edinburgh.

(Read 14th May 1882.)

It seems desirable to put on record the occurrence of two decapod crustaceans in the Wardie shales. They are: *Palæocrangon* sp., and *Anthrapalæmon Traquairii*, B. N. Peach, which, with *Anthrapalæmon Etheridgii*, B. N. Peach, previously noted * by me as occurring on the same general horizon, viz., above the sandstone at Craigleith Quarry, near Edinburgh, make up the total number of decapod species as yet recorded from the Wardie series. The bed occurs near the top of the shales according to some, near the bottom according to others. It contains besides crustaceans, lamellibranchs, cephalopods, and fishes.

It is noticeable that both of the genera enumerated occur in the Lower Carboniferous rocks of both Central and South Scotland, and that the two species of *Anthrapalæmon* likewise occur in the two localities, both having been recently described from Eskdale by B. N. Peach, Esq., F.G.S., to whom I am indebted for the determinations.

* "Trans. Ed. Geol. Soc.," vol. iv., p. 97.

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XVIII.—*The Surface Geology of the Estuary of the Forth —Additional Notes.** By H. M. CADELL, B.Sc.

(Read 4th May 1882.)

I. GEOLOGICAL CHANGES IN PROGRESS.

No historical sketch of the Estuary of the Forth can pretend to completeness which does not include a notice of the agents at present contributing to its geological development. As the remarks in the paper on this subject published in our last session's "Transactions" were intended to be chiefly of a retrospective kind, I shall do little more than indicate the nature of these agencies, in the hope that at no distant date some enterprising geologist will make such a full and systematic investigation of the subject as it well deserves.

1. *River Transport of Sediment.*—The amount of sediment annually brought down by the Forth has, so far as I am aware, never been ascertained, even approximately. It is of interest to note that the Clyde, according to Mr John Dougall, holds in suspension during floods $\frac{1}{100}$ by bulk of solid matter. The Nith has been shown by Professor Archibald Geikie to carry down an amount of sediment which proves that subaërial denudation is lowering its basin at the rate of 1 foot in 4723 years, but with these exceptions little progress has been made in Scotland in the elucidation of this most interesting problem in physical geology.† I have noticed that mud is deposited at the rate of more than 2 feet per annum in quiet corners of the Firth near Bo'ness. A considerable area of rich agricultural land has been reclaimed from the alveus at Kincardine by allowing the mud to settle inside an enclosure between tide-marks, and several proposals have been made to reclaim in a similar way the vast expanse of mud which stretches between Bo'ness and Grangemouth, and which is covered by a very few feet of water at each tide, but for several reasons they have hitherto always been frustrated.

2. *Geological Agency of Man.*—(*a*) The drainage and reclamation of the waste moorlands of the upland districts, which have been going on for many years, render them less retentive of rain water, so that the discharge of the rivers during floods is greater than formerly, and as it is the floods which are chiefly instrumental in transporting sediment, there must be a greater quantity of coarse detritus brought into the estuary than when

* The first paper appears in "Trans. Geol. Soc. Edin.," vol. iv. p. 2 (1881).
† See "Climate and Time," p. 332.

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the flow of the rivers was more equable. It is proper to notice, however, that drained land is conducive to a diminution of rainfall, and the average temperature is sometimes raised as much as $1\frac{1}{2}°$ to 3° F., which is equal to a change of latitude of 100 to 150 miles nearer the equator.* (*b*) In the Coal Measure and Carboniferous Limestone districts especially, where the minerals (so-called) are excavated on the "long wall" system (in which the whole seam is removed, and the roof let down on the pavement) the mineral workings cause:—1st. *An alteration of the contour and coastlines.* Where seams are situated at a depth not exceeding 100 fathoms, subsidence from the working of say a 4 feet seam has been known to amount to 3 feet at the surface; below that depth the subsidence of the surface decreases till at 300 fathoms it is scarcely perceptible.† The total thickness of coal in the lower part of Borrowstounness coalfield is about 15 feet,‡ and at present few of the seams are worked at depths approaching 100 fathoms, so we may easily imagine a subsidence of 11 feet to take place in the course of a few years over a considerable area were they all excavated methodically. *Subaërial* denudation acting at the same rate as that at which we have seen the drainage area of the Nith to be lowered, would thus require $11 \times 4723 = 51{,}953$ years to effect what can be done by human *subterranean* denudation in the course of less than a lifetime.

2d. *A thickening of the estuarine deposits* when subsidence takes place below high water mark. Several years ago the advancing tide might be seen approaching the beach in the form of a long tongue, which filled a hollow produced in this way on the surface of the mud to the west of Bridgeness. The foreshore has now, however, almost regained its former level by the increased deposition of mud over the depressed area.

3rd. *A partial fracturing of the superincumbent strata* along the axis of the wave of subsidence which on the surface follows the course of the working faces below ground. The broken strata are thus rendered an easier prey to denudation, and all deep seated springs occurring within the fractured area are at once tapped.

The same remarks apply to the "stoop and room" or "pillar and stall" workings, where the roof is supported by unworked portions of the seam called "pillars" or "stoops," and ought not to subside till these are removed. In the old workings, before the introduction of the long wall system, the pillars were often left standing, so that at some places the ground is quite honeycombed, and ugly bottle-shaped holes frequently fall in to a

* Geikie's "Phys. Geog.," p. 355.
† "Trans. Manchester Geol. Soc.," vol. ii. p. 16.
‡ "Trans. Geol. Soc. Edin.," vol. iii. p. 312.

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depth sometimes reaching 5 fathoms, without giving any previous warning at the surface.

The waste products of the coal and iron works (shale, slag, ashes, &c.) when emptied out on the foreshore help to increase the land, and thus to counteract the effects of subsidence. Many acres have in this way been snatched from the grasp of the waves between Kinneil and Bridgeness. The shore thus formed is quite porous, and is filled with water at every tide for a considerable distance inland. It is this water which finds its way down into the submarine workings, and not the water from the bed of the Firth, which is almost entirely kept out by the thoroughly impervious bed of red glacial clay which, as I stated in my former paper, covers the floor of the whole estuary.* During spring tides a perceptible increase is experienced in the quantity of water in the workings, and the pumps have to be kept going longer than during neaps, when the beach is covered by the tide for a shorter period and to a less depth. Mr Milne Home, in his paper on the "Supposed Upheaval of Scotland," † gives a sketch showing the termination of the ancient natural beach line at Bridgeness (Plate I., sketch 1, line F F F F). It is composed, first, of fine sand and gravel, which fringes the base of the old sandstone cliffs, and secondly, of an outer belt of the broken shells to which I have alluded in the former paper (*loc. cit.* p. 22). The shells which probably formed the beach at the time of the Romans pass under a more recent beach of ashes from the saltpans, worked extensively all along this coast at the beginning of the century, and which have given names to such villages as Grange-*pans*, situated between Bridgeness and Bo'ness, and Preston-*pans* in East Lothian. The salt making of the district is now represented by one solitary pan in Grange-pans, and it, too, will probably, as years roll on, be improved off the face of the earth like its predecessors, not being able to compete with the natural pans in which most of the salt now used was crystallized under the skies of the remote Triassic period. The stratum of pan ashes is in turn overlaid by the more recent accumulations from the coal and iron works, which are now the chief industries of the district. The crevices between the particles of debris soon become filled with mud filtered from the turbid water, so that were these deposits to become consolidated into rock, the geologist of the future would find here a coarse breccia, partly aqueous and partly igneous in origin, firmly cemented in a matrix of consolidated mud, and representing, in different strata, the various stages in the industrial history of the district.

* See also "Trans. Geol. Soc. Edin.," vol. ii. p. 41.
† "Trans. Roy. Soc. Edin.," vol. xxvii.

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II. The Chemistry of the Glacial and Recent Clays.

Our excellent Secretary, Mr W. Ivison Macadam, F.C.S., F.I.C., has kindly made the following analyses of samples of the red glacial clay and of the greenish Carse clay of the district:—

Analyses of Clays.

	Red Clay.			Carse Clay.	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Soluble in Acids—					
Ferrous Oxide, FeO	1·972	1·724	1·151	1·232	1·456
Ferric ,, Fe_2O_3	5·390	5·529	5·240	2·202	2·411
Aluminic ,, Al_2O_3	4·673	4·142	3·838	2·116	1·837
Calcic ,, CaO	1·428	1·676	1·462	1·408	1·242
Magnesic ,, MgO	0·734	1·029	1·072	0·889	0·594
Carbonic Anhyd. CO_2	1·656	1·878	1·133	2·054	2·856
Soluble Silica, SiO_2	1·114	1·316	1·052	1·215	1·031
	16·967	17·294	14·948	11·116	11·427
Decomposed by Hydric Fluoride—					
Potassic Oxide, K_2O / Sodic, . Na_2O	0·633	0·875	0·764	1·042	0·941
Fused with Alkaline Carbonates—					
Ferric Oxide, Fe_2O_3	1·358	1·156	1·042	0·654	0·742
Aluminic, Al_2O_3	19·565	21·338	18·456	8·720	8·480
Calcic, . . CaO	0·791	0·879	0·766	1·414	1·804
Magnesic and undetermined, . .	0·245	0·186	0·224	0·185	0·174
	21·959	23·559	20·488	10·973	11·200
Insoluble Silica, .	55·166	53·404	58·068	70·865	71·809
Loss on ignition—					
Water, . . . / Organic Matter, .	5·275	4·868	5·732	6·004	4·623
	100·000	100·000	100·000	100·000	100·000

	Other Clays.		
	A	B	C
SiO_2	50·5	64·1	53·7
FeO . . . . / Fe_2O_3	1·8	1·8	1·4
Al_2O_3	33·7	23·1	32·0
CaO	...	...	0·4
MgO	0·8	0·9	...
Na_2O	1·9	...	...
Moisture	11·2	10·0	12·1
CO_2	...	...	...
	99·9	99·9	99·6

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These analyses, unaccompanied as they are by any extensive microscopic examination (without which it is impossible to form a strictly accurate estimate of the proximate mineral composition of any clay), show that the red clay of this part of the estuary possesses a tolerably uniform composition. Sample No. 1 was taken from the surface of the clay in Bo'ness Dock, No. 2 was got from No. 6 Pit at Bridgeness, and No. 3 is from the tile-work at Blackness, where the clay is worked at a height of a little more than 50 feet above sea-level. The red clay, compared to the overlying carse clay, is seen to be pretty pure in composition. Theoretically, a pure clay consists of the hydrous silicate of alumina (Al_2O_3 $2SiO_2 + H_2O$), having the composition—silica, 46·3; alumina, 39·8; water, 13·9,* but practically this degree of purity is never attained to; one reason probably being, as Sorby has pointed out, that a complete separation of clay from sand seldom takes place, because the particles of kaolin have a very great tendency to stick together and collect into complex granules, and in so doing may enclose grains of sand.† Besides the free silica thus present there are other impurities, such as lime and oxide of iron, which give rise to the different varieties of clay. "Clay" is thus a term only descriptive of a mechanical mixture, and not of a true chemical compound. Column A gives Professor Bloxam's analysis of Chinese kaolin (the purest known clay). The silica there bears to the alumina the proportion 50·5 : 33·7, the same two components of the red clay in the purest sample (No. 2) have the relation of 55·12 : 25·480. In B we have an analysis of fire-clay from Stourbridge. There is here a large preponderance of silica, and a total absence of alkalis and lime, which have, in most carboniferous under-clays, been abstracted by the vegetation growing on them; and it is to their absence that the infusibility of the clay at high temperatures is mainly due. The composition of pipe-clay is given in C, where it will be seen that the silica is to the alumina as 53·7 : 32—a slightly closer approximation to the proportions of these materials in the red clay than subsists in A. Pipe-clay is also noted for its infusibility at high temperatures, and is seen to contain no alkalis; but these constituents of the red clay render it so fusible that it is unable even to withstand the heat of the ordinary "biscuit" kiln. The purity of the red clay as compared with the overlying carse clay is an additional proof of its having been deposited in tranquil water. Had the proportion of silica to alumina been much greater, the excess would probably have been due to the presence of sand, the grains of which would have required much stronger currents than were necessary for the transport of

* Rutley's "Mineralogy," p. 130.

† "Monthly Microscopical Journal," 1877, Anniversary Address, p. 15.

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the fine particles of clay. Sorby (*loc. cit.*) has found that grains of sand $\frac{1}{100}$ of an inch in diameter subside a foot in ten seconds, while the smallest grains of kaolin take about *five days* to descend through the same space. The slight microscopical examination which I have made shows that there are many fine sand grains in the glacial bed, but no lens is required to detect the sand which forms such a large percentage of the carse clay, both specimens of which are from Bo'ness Dock. The iron in both clays occurs partly in the ferrous and partly in the ferric state. I attributed the green colour of the carse clay to the presence of organic matter at the time of its deposition, which reduced all its iron to the ferrous state, and the red colour of the glacial clay "to its freedom from organic remains" (*loc. cit.*, p. 15); but I have since discussed the matter with Mr Murray of the "Challenger" expedition, and with Dr J. J. Dobbie of Glasgow University, and both these authorities agree that the condition of the iron in the two clays is no criterion as to the amount of organic matter present during their deposition, although it is quite possible there *may* have been more organic matter present in the one case than in the other. The analyses show that in both cases the ferric is in excess of the ferrous oxide, and I would now, therefore, take the opportunity of withdrawing this argument from those I adduced in favour of the hypothesis that the waters of the last glacial sea were almost devoid of life. (Page 15.)

III. Additional Notes.

1. *Buried Channel of the Devon.*—I have recently obtained the journals of several borings made in the valley of the Devon at Alva, at different times between 1826 and 1872. These show clearly that there is here, as at other localities, a well-marked buried river channel filled up with glacial and interglacial deposits. The most conspicuous beds are a fine blue clay from 8 to 20 fathoms in thickness, which rests on a fine red clay generally a few fathoms thicker, whose maximum thickness, as found in the bores, is a little over 25 fathoms. This clay, like the red clay at Bo'ness, is usually separated from the underlying till by a bed of sand or gravel of variable thickness. The till, which is generally of a red colour, is sometimes separated from the rock surface by a bed of sand or gravel, which, like that at Low Valleyfield is probably a patch of the ancient river detritus which once covered the bottom of the valley.

As there was no indication of the exact position of the majority of the bores on the journals in the possession of Messrs John and G. H. Geddes, M.E. (who have kindly allowed me to copy them), it is needless to discuss the subject more fully; but I

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hope at some future date to obtain the desired information whereby another link may be added to the chain of evidence of a general rise of the sea since the time of preglacial Europe.

2. *Colliery Disaster at Crombie.*—I have recently received corroboration of the tradition about the accident at Crombie Colliery last century, to which allusion was made at page 7. Mr William Hurst, late locomotive superintendent to the N. B. Railway, who is himself a native of Torry, tells me that sixty years ago an old collier in Fordell (near Inverkeithing), named William Ramsay, stated that his grandfather, who was a slave, had lost his life in the disaster. Mr Hurst could not remember any further particulars than that the mine was flooded a short time before the colliers received their liberty.

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XIX.—*Notes on the Glaciation of Norway and Scotland.* By H. M. CADELL, B.Sc.

(Read 4th May 1882.)

Norway, like our western Highlands, is a huge table land or plain of marine denudation, composed almost entirely of metamorphic rocks of pre-Devonian age. The deep fjords which run far inland divide the plateau into well-marked regions, on one of which, cut off by arms of the beautiful Hardanger Fjord into an approximately triangular peninsula, rests the Folgefond, the most southerly snow-field in Norway. Last autumn I paid a short visit to this glacier while staying at Odde, a village situated at the head of the Sör Fjord, a long hook-like arm of the Hardanger, and had an opportunity of forming some idea of the condition of Scotland while passing through the latest phase of the Glacial Period.

The ascent of the Folgefond was made by the Buarbrae (*brae* being the Norwegian for *glacier*), one of the three glaciers which flow from it. The four great groups of European glaciers, those of the Pyrenees, Alps, Caucasus, and Scandinavia, as well as those of Greenland and Spitzbergen, all show a retreat of the ice,* but the ice of the Buarbrae has been constantly advancing since it was visited by Professor Sexe in 1864.† It has advanced 40 metres between 1860 and 1878, and is now within 200 metres of cultivated fields.‡ Sexe (*loc. cit.* p. 9, fig 10) gives a sketch plan of the glacier in 1860, which shows a ridge of rock with three protuberances, running nearly across the root of the Buarbrae, where it leaves the Folgefond. The glacier performs a wheel three-quarters-to-the-left-about round the southern end of the ridge, and passes in a comparatively narrow stream into the valley below, where it again expands. Dr Albrecht Penck visited it in 1878, and found that the ice had so increased as to overflow the lower parts of the ridge, leaving nothing but two of the rocky hummocks protruding. When I visited it last year there were three such knolls, which appear to correspond with the three shewn on Sexe's sketch of 1864. Penck§ gives a sketch map of the glacier at both periods, and the third rock must either be part of the central mass shown by Penck (now

* Prof. C. Dufour on the Retreat of the European Glaciers. "Pop. Science Rev.," Oct. 1881.

† Om Sneebräen Folgefon, Christiania, Universitets programm andet Halvaen, 1864.

‡ *Nature*, vol. xxv. p. 449.

§ Penck's paper, "Die Gletscher Norwegens," Mittheil. des Vereins für Erdkunde zu Leipzig. 1879.

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divided into two), or it must be due to the ice overflowing the remaining northern part of the ridge at the root, and leaving the snout uncovered. I suspect, however, that Penck's sketch map is not so accurate as that of Sexe, which would show the three peaks isolated from one another so as to divide the upper part into four streams, were the glacier to increase in size.

J. Innes Rodgers in a letter to *Nature*, vol. xxv. p. 460, states that he visited the place in 1874, and heard from a guide at Odde, Asbjörn Olsen by name, a legend of how the Buer valley had long ago extended far into the mountains, and had contained a village, church, and pastor, with farms and cultivation. One winter night the inhabitants refused shelter to three Finns (Lapps) from a fearful storm about to break, and this so enraged the heathen wizards that they cursed the valley and doomed it to destruction by the crawling ice of the glacier. It advanced by awful steps, and by degrees engulfed the cursed valley and farms; nor is the curse yet exhausted, for the glacier creeps down the valley each year, and has yet a mile to go before it reaches its destination in the lake above Odde. This story is no doubt very pretty, and at first sight sounds plausible enough, but I suspect it had either been invented for the occasion, or is one of those legends which are remembered only when some disaster is threatened. The fact that a ridge of rock runs nearly across the head of the glen only a few feet below the surface of the ice is of itself a clear enough proof that the valley cannot possibly extend far into the mountains, but Sexe in his paper (*loc. cit. Résume du programme pour les étrangers*, p. viii.) expressly states that no such tradition existed when he was there, for to use his own words, "Si le Folgefon s'était accru depuis que le pays est habité, il existerait dans les contrées voisines des légendes et des traditions à ce sujet car un pareil acroissement aurait touché aux intérêts du voisinage. En ce cas le Folgefon aurait successivement envahi les prés de châlets des vallées les plus rapprochées. Mais il n'y a pas de tradition d'une augmentation successive et générale du Folgefon. Il est donc vraisemable qu'il ait conservé de temps immemorial son étendue actuelle."

Penck (*loc. cit.* p. 7) seeks to account for the advance of the glacier by supposing a tremendous snowstorm to have occurred, in which the snow was swept into a heap on the east side of the "fond" above the Buarbrae, resulting in an acceleration of the glacier, which has not yet ceased to advance. It seems to me very difficult to conceive how any storm could pile up the snow to such an extent that the additional local pressure then produced would not be relieved after twenty years' time. Had there been a succession of storms which each year increased the depth of snow above the glacier, then it would be more easy to accept

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Penck's explanation, but I hardly think we are justified in coming to any definite decision as to the cause of the forward motion of the Buarbrae until we are in possession of more extended meteorological information about the district than is at present obtainable. That the advance of the glacier is purely a local phenomenon is evident, and it is quite probable that it may ere long begin to retire. Helland, in a valuable paper on the Glaciers of Greenland, &c.,* states that many of them advance and retire irregularly, that of Sorkak, for example, having in the course of two generations receded and advanced several hundred ells, but their motion gives no proof of a uniform increase of ice in North Greenland.

The way in which the Buarbrae is ploughing up the turf and gravel before it is well illustrated by Credner in a paper, "Schichtenstörnungen im Untergrunde des Geschiebelehmes," figs. 1, 2, 3 (Zeitschr. d. Deutschen Gesellschaft, Jahrg. 1880). The heavy rains of the previous summer had washed off most of the snow from the surface of the Folgefond, showing it to be, as Penck points out, a great sheet of ice covered by a surface layer of snow or "firn." This blue ice often forms a wall or precipice round the edge of these Norwegian snow fields. It is seen at parts of both the Folgefond and the Justedal—a much larger snow field, situated along the south shore of the Sogne Fjord, which enters the sea at Bergen. Professor A. Geikie, in his recently published "Geological Sketches," speaking of the Jökuls Fjeld—a still more northerly snow field—(p. 160), says, "We could see that at the far end of that inlet the snow of the great table-land moves outward to the edge of the dark precipices which encircle the Ulfjord, and actually forms on the crest of these precipices a white cliff, from which, of course, avalanches are constantly falling. Yet the under part of this snowy cliff is not snow, but ice, as shown by its blue colour contrasting with the whiteness of the upper layer, which is snow or *névé*." Forbes, in his delightful book, "Norway and its Glaciers," concludes that the glaciers of that country differ from those of the Alps in no essential particular. Penck, however, maintains that there *is* a fundamental difference between the two groups of glaciers, and it is this: the glaciers of the Alps originate in sloping "Firnfelds," while those of Norway are the overflows of inland ice-sheets. Three glaciers, for example, descend from the Folgefond — the Bondhuusbrae, Buarbrae, and Blaadalsbrae, while the ice of the Justedal glacier overflows by no less than twenty valley glaciers, or "Glaciers of the First Order," as Saussure has named them. I agree with Penck in considering these large snow fields, or Glaciers of the Second Order, to be nothing less than ice-sheets, akin to that now covering Green-

* "Quart. Journ. Geol. Soc.," vol. xxxiii. p. 154.

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land, and which, during the Glacial Period, extended over the whole of Northern Europe, and produced the grander glacial phenomena of North Britain, with which we Scotsmen are so familiar. If Forbes had lived to see the development of Croll's ice-sheet theory, I have no doubt he would speedily have recognised it as the true method of explaining the groovings on some of the higher mountain masses for which he admits he was at a loss to account by the means of the ordinary valley glaciers.

Helland (*loc. cit.*, p. 153) points out that a great snowfall is not absolutely necessary for the glaciation of an extensive country, and that a large number of the Greenland glaciers are supplied by an ice-sheet lying below the snow line, and doubts if the ice would re-form if once cleared off the country. Forbes apparently held somewhat similar views, and it seems to me that if the surface of the ice-sheets be below the snow line, much more must this be true for the rocky platforms on which they rest, and hence we have almost proof positive, on this ground alone, of a great extension of the ice in former times.

The Folgefond has an area of about 14 English square miles, and reaches a height of a little over 5400 ft. above sea level. The magnificent view from the summit when I visited it was partially obscured by mist, but we got several glimpses of the surrounding mountain masses which at some places just touched the clouds, and stretched away on all sides towards the horizon like the billowy surface of an angry sea, forcibly impressing on the spectator's mind the truth of the observation that Norway has not been squeezed up into a mass of jagged and contorted peaks like the Alps, but is the result of the subaërial denudation of an old land surface of hard metamorphic rocks, originally worn down to sea level, and subsequently re-elevated as an approximately level plain of marine denudation, the highest summits of which (8500 ft.) do not rise to an abnormal height above the neighbouring mountain tops. The rocks appearing from below the ice were typical *roches moutonnées*, and a short distance off they were covered with perched blocks of various sizes resting where the retiring ice had left them. I noticed a large boulder resting on the crest of a ridge with a smaller one on its back, which, had it been seen in Scotland, would in all probability have been triumphantly claimed by the upholders of the iceberg theory as affording unmistakable evidence of former submergence.

The fjords, to which I have already incidentally alluded, are another very striking feature in the physiography of Norway. That they have not been formed by volcanic agency of any kind is obvious, for there is no trace of recent volcanic activity in Norway, nor is there any evidence of great local subsidences or fracturings of the rocks in their vicinity. They bear, on the other hand, marks of the most intense grinding by land ice at a

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very recent date, and the remnants of the glaciers which have presumably hollowed them out are now to be seen lurking in many of the upland valleys from whence the fjords begin. They are, I think, the most typical examples of true ice-formed rock basins to be found in this quarter of the globe, and I am surprised they have not been described more fully by British glacialists as supplying the most convincing proofs of the eroding power of glacier ice. Helland, Du Chaillu,* and others give the depths of several of the principal fjords which have been surveyed by the Norwegian Government, and all the soundings show the depth to be less at the mouth than further inland. While the North Sea does not generally exceed 50 fathoms in depth, soundings of from 200 to 300 fathoms are quite common in the fjords. The greatest depth of the Hardanger Fjord is, for example, 800 metres (or 2625 feet), while the gigantic Sogne Fjord is no less than 1244 metres (4080 feet) deep in its inner part. They are sometimes prolonged seawards for several miles as well-marked hollows, with their extremities surrounded by gravel shoals, which, if an upheaval were to take place, would appear as moraines facing the lake basins of the fjords.

Evidences of glaciers have been found at a height of 569 metres on the island of Varaldsö in the middle of the Hardanger Fjord. The depth of water inside this island is, according to the sea charts, 631 m., so that there must have been a thickness of at least 1200 m. (3937 ft.) of ice in the fjord during the glacial epoch. Similar calculations by Helland show that the glacier in the Sogne Fjord must have been not less than 1755 metres (5758 ft.). Lateral glaciers 800 meters thick flowed into these fjords from an ice-sheet at least 800 to 1100 m. in thickness. The enormous pressure to which the underlying rock would be subjected when filled by a glacier say only 5000 feet thick may be seen if we consider that a column of water about 2·3 feet high will give a pressure of 1 lb. per square inch, which will be equivalent to a column of ice about 2·5 ft. high (the specific gravity of ice being taken at ·9); the whole pressure on the bottom of the valley would therefore be $= 5000 \div 2{\cdot}5 = 200$ lbs. per square inch. If a hard stone were pushed along the rock surface with a weight like this on its back is it any wonder if it should form a deep groove, and by a repetition of the process scoop out a valley? Surely not.

In winter some of the fjords are frozen over with a cake of ice which rises and falls with the tides in the same way as the ice may have done on the Firth of Forth during the period when the red glacial clay was being deposited as fine mud ground off the rocks by glaciers which filled the distant glens, as the glaciers do at the present day in Norway.

* "Land of the Midnight Sun," vol. i.

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XX. — *Further Notice of the Tigh-na-criche Shell-Bed, Loch Fynne, Argyllshire.* By W. Ivison Macadam, F.C.S., F.I.C., &c., Lecturer on Chemistry and Analytical Chemist, Edinburgh, *Honorary Secretary to the Society.*

(Read 4th May 1882.)

In the first part of this volume of "Transactions" (page 94, part i., vol. iv., "Transactions Geological Society of Edinburgh"), a paper is printed in which the author gives the results of his investigations carried out during the summer of 1880. The following summer (1881) the bed was subjected to a close search, and the material found was handed to Mr David Robertson of Glasgow, who, with his customary kindness named the specimens. The following is the list of species as furnished by Mr Robertson :—

List of Mollusca from Clay-Bed at Tigh-na-criche, Strachur, Loch Fynne.

Balanus procutus.
Balanus crenatus.
Anomea ephippium, Linn.
Pecten Islandicus, Müll.
Pecten varius, Linn.
Mytilus modiolus, Linn.
Lucina borealis, Linn.
Cyprina Islandica, Linn.
Astarte compressa, Mont.
Astarte sulcata, var. *elliptica*, Brown.
Tellina calcaria, Chemn.
Mya truncata, Linn.
Littorina littorea, Linn.
Natica affines, Gruelin.
Natica Grœnlandica, Beck.
Buccinum undatum, var. *striata*, Penn.
Fusus antiquus, Linn.
Pleurotoma turricula, Mont.

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XXI.—*On the Origin and Age of Quartz Veins in the Strata in the Neighbourhood of Falmouth.* By ALEXANDER SOMERVAIL, *Associate.*

(Read 4th May 1882.)

The existence of quartz, either as forming rock masses, or as occurring in them (with the exception of certain sedimentary rocks, like siliceous sandstones, which are almost wholly made up of quartz grains derived from the waste of pre-existing rocks, and not of primary origin), may be said to be due to three well defined causes.

First. To organic agency, or the power possessed by many of the lowly forms both of plant and animal life, like the *Diatomaceæ* and certain of the sponges which secrete silex from the waters of the ocean, building it up into these solid parts which form their framework or skeletons.

This origin of silex would seem, in one way or another, to account for the great layers of flint nodules so common in the white chalk, also in many of the more thickly bedded carboniferous limestones. The simple forms not only secrete it while alive, but even after death the decomposition of their bodies apparently attract it.

Second. To Plutonic agency, or that deeply seated internal heat which has given rise to, or accompanies the production of, granite and other allied rocks, in which silica is an abundant or a predominating constituent, as well as to quartz in its more pure and crystalline form, together with all those varieties of it which have passed from a molten condition to a solid state, by a process of slow cooling, at a great depth and under immense pressure.

Third. To deposition from solution, or to that power which enables water at a high temperature, or water highly impregnated with certain acids, to hold silica in a soluble state, and in cooling to part with it, or under other conditions to leave it behind as a deposit forming layers, or filling up cavities, joints, and fissures through which it has flowed.

To this latter cause or process we would attribute the formation of the numerous veins of quartz which occur in the strata in the neighbourhood of Falmouth. Those veins are certainly extraordinary both as regards their number and thickness. They occur from the size of mere threads up to masses of several feet in width. The largest example is a vein of nearly 4 feet in thickness, and which is quarried near the old Penryn Road.

These veins can be best studied on the shore, where they are

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found traversing the strata in every direction, running at right angles to the strike, occurring between the bedding, and even inserting themselves between the laminæ. They cross and recross each other forming a perfect network, especially among the more thinly bedded rocks. The veins sometimes radiate from a central mass of considerable extent, thinning rapidly out, and again increasing in thickness and frequently splitting up into smaller ones, spreading hither and thither in every direction, sometimes changing the strata to such an extent, that in certain beds the quartz greatly predominates over the slate. The walls of the veins are in most cases well defined, but in others the quartz has so spread itself, or permeated into the matrix of the slate, as to completely alter the original texture of the rock.

Very few of the veins show signs of successive deposits. They rather bear out the idea that deposition went on regularly and without any interruption.

The minerals or mineral matter associated with the veins is very sparing. Some of them are more or less coloured with the peroxide of iron. The walls of the veins, on their margins, contain chlorite, which has apparently been developed or brought more closely together by the action of the heated water.

The origin and age of these veins of quartz appear to be intimately connected with, and both contemporaneous with and subsequent to the formation of the great masses of granite, which form the long ridge extending from the Lands End into Devonshire. They are, however, more especially related with that mass of granite which lies a little to the west of Falmouth, and which I have no doubt is joined, in its deeper seated portions, with the other masses referred to, and which form the watershed of Cornwall and part of Devon. During the formation and upheaval of the granite the amount of fracture produced among the adjoining slates would be great. They must have been rent in every direction. Those rents and fractures certainly afforded the principal channels in which the quartz was deposited.

We now know that during the formation of granite and other igneous rocks that water is always present. Even in quartz, which enters so largely into the composition of granite, water is found filling small cavities. In the neighbourhood of certain volcanic regions hot springs abound, and contain much mineral matter in solution. Silica does not appear to be a plentiful product of recent volcanoes; indeed it is so sparing in both old and recent lavas, that the microscope has been required to detect its presence. In the older series of igneous rocks, termed the Trappean, it is much more abundant, but it is only when we come to the Plutonic rocks, of which

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granite is the type, that we find silica becoming the predominating element.

The water, which must have accompanied the formation of the granite, must have been at a high temperature, and highly charged with silica. This water, forcing a passage through the ruptured slates, would, on cooling, naturally part with the excess of silica held in solution, coating the walls of the rents and joints until they were completely filled up, leaving a great network of quartz veins.

That this process was long and continuous the veins afford evidence. Some of them, especially the smaller ones, appear after their formation to have been again fractured and filled by other deposits.

Even the granite appears to have some of its joints and fractures, consequent on cooling, filled with quartz. Such examples may be seen near the line of juncture with the strata, in that portion of the granite termed gossan.

These veins in the granite may have been filled during its semi-consolidated state, or at a period, geologically speaking, not long subsequent to its consolidation. Those in the slate may have commenced from the earliest period of activity, and continued up to the time of those in the granite, or even after their formation, yet all, strictly speaking, belonging to one and the same period of geological time.

If we can fix approximately the age of the granite, we can do the same for the formation of the veins; and this is a task of no great geological difficulty. The long, though partially detached, ridge of granite to which we have already alluded, doubtless forms the same extension in its deeper seated portions.

The highest rocks in Cornwall (Upper Devonian) are disturbed and broken through by the granite. In Devonshire the evidence is much more satisfactory and complete. In that county the granite not only disturbs, but indurates and breaks through true Carboniferous beds, and which contain characteristic fossils. Further, upon the very edges of these disturbed and indurated Carboniferous rocks, Permian or New Red Sandstone beds are deposited quite undisturbed, and, I believe, containing in some portions pebbles of the granite, clearly proving them to be of later age than the granite. Thus we have a decided clue to the age of the granite, and which is clearly of Carboniferous age; therefore we have no hesitation in ascribing the quartz veins to the same period of geological time.

But there is still another line of evidence we are able to pursue. This evidence is derived from the examination of certain trap dykes or elvans associated with the strata. Some of those trap or old volcanic rocks appear to be contemporaneous with the strata among which they occur: that is, they have

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been poured out as lavas over the surface of the slates, and new deposits of sediment spread over those cooled and hardened surfaces. There is an example of this kind on the shore near Mawnan, in which veins of quartz run through both the trap rock and the adjoining strata, proving that the quartz veins are newer than the strata and the trap through which they pass.

Both the strata and trap would seem to have been formed in the usual horizontal position, and afterwards tilted up on end by the granite which ruptured both; those ruptures and joints in the trap and slate being afterwards filled up by a deposit of quartz from the water accompanying the formation of the granite.

There are others of the dykes or elvans termed mica traps occurring near to Tremissick Point and Trelissick. Those traps are of much more recent date than the strata through which they pass, as they disturb the beds and indurate both surfaces of contact. The adjoining strata contain numerous quartz veins which are entirely absent from the trap beds associated with them—a fact clearly proving them to have been injected among the strata at a period when the quartz veins had ceased to be formed.

There is another subject closely connected with the formation of the granite and the quartz veins, viz., the metamorphism of the strata. In the whole district round about Falmouth the strata have undergone a very great change from the original condition in which they were deposited. This change has not only altered the strata at its junction with the granite, but widely apart from it. In this metamorphism or change, while recognising the effect of the granite, we would more specially ascribe it to the action of highly heated water passing through the strata, permeating and forcing itself into the very texture of the rocks, changing even the molecular arrangement of the very particles which build them up. This action has not only altered the mineral composition of the beds, but the same cause has destroyed all traces of organic remains which the strata no doubt once enclosed.

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XXII.—*Excursion to Oakbank Shale Pits and Paraffin Oil Works.* Messrs Calderwood and Mitchell, *Leaders.*

10*th June* 1882.

On the invitation of Mr Beilby, manager, Oakbank Oil Works, and Mr Calderwood, manager, Pits, Oakbank, the Society visited these works. The party were met at the Oil Works by Mr Mitchell, chemist to the works, and were conducted over the various operations, from the manufacture of the crude oil out of shale to the refined products, burning, and lubricating oil and solid paraffin. In the Refinery the members were shown by Mr Maxwell, junior, the arrangements for putting out a fire, should such occur, by means of steam blown in from a boiler. The party then proceeded to the shale pits, where they were met by Mr Calderwood, who conducted the members to the underground workings. The galleries, which are somewhat extensive, were traversed, and the methods of "trimming" the shale explained, after which the surface was regained.

Arrangements having been made for dinner at the Torphichen Arms Hotel, Mid-Calder, the party proceeded there. After a hearty meal, Mr Ralph Richardson, W.S., F.R.S.E., Vice-President, proposed the health of the various gentlemen to whom the Society was indebted for an enjoyable day. Mr Calderwood replied. Mr Alexander Cockburn then proposed the health of Messrs Richardson and Macadam, which were suitably acknowledged.

XXIII.—*Excursion to the Silurian Rocks of the Pentland Hills.* Mr John Henderson, *Leader.*

17*th June* 1882.

The party visited the various sections exposed along the valley between Bevelaw Castle and Habbies Howe. The first section examined is exposed about 250 yards south of Bevelaw Castle. Here the Silurian rocks have been quarried for a hard whin, which is used for macadamising the roads.

The Silurian shales stand nearly vertical with the dike or bed conformably between. This has been described as an intrusive greenstone, but the members of the party were inclined to consider it a bed of hard grit of sedimentary origin. Mr Henderson explained that the beds were the highest in the section, and might be considered the equivalent of the upper portion of the Wenlock series, and that as the party went east they would be

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descending in the strata. Proceeding through the long dry valley that cuts the hills transversely from Bevelaw to Habbies Howe, the party examined the sections exposed on both sides of the valley, and especially one about half-way between Bevelaw and Habbies Howe, where the vertical Silurian shales are overlaid by nearly horizontal beds of coarse boulder conglomerate. At first appearance it looked as if the conglomerate had been faulted against the Silurian, but by clearing away the clay the Silurian shales were exposed lying under the conglomerate. Continuing through the valley, which at its western end cuts through a great depth of Silurian rock, and in the eastern portion through felstones and conglomerate, the party examined the large boulder of mica slate lying on the south side of the valley near the east end, which was supposed by Maclaren to have been derived from the Grampians. The company then proceeded to the east end of the valley where it joins the great central valley of the Pentland Hills. A section of the Silurian rocks was examined near where the transverse valley joins the larger longitudinal one near Habbies Howe. At this place the vertical Silurian shales abut on a mass of felstone. The party then retraced their steps for a short distance up the Logan Burn to where the water falls over the rocks at Habbies Howe, where they inspected the great masses of conglomerate cut through by the burn in its passage from the higher valley. In some of the blocks of Silurian limestone that form part of the conglomerate several Silurian fossils were obtained, these being of Wenlock type.

The rain which had been falling in showers during the day now poured heavily, and the party were forced to return to Balerno *en route* for Edinburgh.

XXIV.—*Joint Excursion with the Glasgow Geological Society to Carluke.* Dr John R. S. Hunter, *Leader.*

1*st July* 1882.

In pursuance of what has now come to be looked upon as an annual feature of the excursion programme, the members of the two societies visited Braidwood, in the Carluke district, with the twofold object of seeing some of the more salient geological features of the neighbourhood, and of inspecting the treasures of the well-known collections of Dr J. R. S. Hunter of Daleville, who had kindly invited the party to meet at his house for that purpose.

On reaching Braidwood the party was welcomed by Dr Hunter, and under his guidance proceeded at once to the head

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of Braidwood Gill, near Beanshield House, where, before commencing the more arduous work of the day, luncheon was provided.

Here, almost under their feet, in the steep scaurs could be seen fine sections of the lowest horizon in which carboniferous fossils had been found in the district, and lying immediately over the unfossiliferous strata of the cement-stone series in the calciferous sandstone group.

In this appropriate spot Dr Hunter read a paper on the Geology and Archæology of Braidwood, in the course of which he said that he had much pleasure in again meeting his friends of the two societies on Braidwood ground after a lapse of nearly eighteen years. The musketry of grim death had done much execution amongst the Edinburgh members who had assembled on that memorable day. The names of the pioneers in geological research in Carluke parish are lost in the mists of obscurity, though coal and lime have been worked from very remote periods. Many years ago, while workmen were making some alterations for the Castlehill Ironworks, they discovered an old pit-shaft, about 4½ feet in diameter, of circular form, and used as a spiral stair for taking up the coals. In the old workings baskets of wicker work, somewhat similar to those of the Newhaven fishwives, and with carrying-straps of the same material, were got. A pick was found, about 10 inches from point to point, and formed of four plies of iron imperfectly welded together, one end still retaining a thin tip of steel. The earliest notice of coal being worked in the parish is that in an application to the Kirk Session of Carluke, as follows:—"Sess. 25 August 1650. The q^{lk} day Claud Hamilton of Garein desired liberty to set the water off the Coalhaugh upon the Sabbath morning q^{lk} was granted becaus it was ane wark of necessity." Few parishes have such a great vertical range of strata exposed by outcrop as Carluke, but it would be now impossible to go into particulars. Suffice it to say that there are more than 500 fathoms in vertical depth from the upper coal measures at Law to the strata upon which the party were then gathered—those below the *Productus punctatus* beds at Beanshields. The whole section may roughly be divided as follows:—(1) The lower coal measures, embracing the strata from immediately below the *Productus giganteus* limestone to the calciferous sandstone; (2) the lower carboniferous or mountain limestone, comprising beds from the *Productus giganteus* limestone to the *Lingula* limestone; (3) the middle coal measures, embracing strata from the gas or cannel coal to those immediately above the Carluke "first" coal; and (4) the upper carboniferous limestone, comprising strata from the Howgate limestone to the strata above the Gare limestone. There are numerous dislocations of strata in the

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parish from igneous action. A huge dyke brings the Gare beds at Whiteshaw, Carluke, back to the west, the Kiltongue coal being on the other side, indicating a displacement of upwards of 150 fathoms. Another large fault can be traced from near Lee House, passing Braidwood onwards to Mauldslie Law. It brings down the middle coal measures against the lower carboniferous limestone series, or a hitch of about 80 fathoms, the gas coal and *Productus giganteus* limestone being seen nearly on the same horizon at John's Brae, Braidwood Gill. Numerous minor faults or dislocations are observable, both in the coal and limestone series, and cause a vast amount of trouble and expense to the mineral workers. Dr Hunter then entered into details regarding the palæontology of the district, making a start from the lowest beds where organic remains were first found by Dr Selkirk of Carluke many years ago, and gradually ascending the section, and giving, by means of stratigraphical and palæontological details, a correct idea of the contemporaneity of fossils, and of the frequent changes of condition under which the flora and fauna of the carboniferous period existed.

The party, after hearing Dr Hunter's interesting sketch, proceeded down the edge of, but outside, Braidwood Gill to a section of strata in the richly fossiliferous beds of the *Lingula* ironstone series, and in which *Lingula squamiformis* is the characteristic fossil. Here masses of the strata had been detached by several of Dr Hunter's men, and soon hammers and chisels were in full activity, and a considerable number of characteristic carboniferous specimens were obtained. The members then proceeded to Daleville House and inspected the treasures, geological and archæological, with which the house is filled. The party were heartily entertained by Dr Hunter in his house. At the close of the repast,

Mr John Young, F.G.S., in the name of the Geological Society, Glasgow, proposed a hearty vote of thanks to Dr and Mrs Hunter for the kind hospitality with which they had received the two societies. Mr Young said that this was not the first occasion on which members of the society had been entertained by Dr Hunter, and many present would gratefully remember former entertainments on their visits to the district during the past twenty years. In conclusion, Mr Young said that he was sure he was expressing the sincere wish of all present that Dr and Mrs Hunter might be long spared in health and strength to carry on the work of adding to and completing the "Braidwood Collection," and to exercise the same bountiful hospitality which the party had that day experienced in their visit to Daleville.

Dr Black, Edinburgh Geological Society, for himself and his fellow-members, cordially reciprocated the sentiments expressed by Mr Young.

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Dr Hunter, in reply, said that it had not only given him that day much pleasure to see the members of the Glasgow and Edinburgh Geological Societies once more assembled under his roof, but that he hoped those of them who were pursuing scientific investigations, and who wished to collect specimens or obtain further information, would not be backward in calling upon him at any time, for he could assure them always of a hearty welcome at Daleville. For himself and Mrs Hunter he had to express his sincere thanks for the hearty good wishes which had been expressed by Mr Young and Dr Black, and to hope that at no distant date he would again be able to welcome the party at Daleville.

Mr Murdoch, Secretary of the Geological Society of Glasgow, begged to propose the continued prosperity of the Edinburgh Geological Society. It had now become almost an "institution," as the Americans say, that the two societies should have a common meeting ground at least once a year, and this was the fifth annual occurrence of such a gathering. On these previous occasions the joint party had visited Midcalder, the Pentland Hills, Bathgate, and Beith, and he hoped that the scenes of future excursions would prove as full of interest as these had been. In connection with the Edinburgh Geological Society, he begged to couple the name of one of its well-known working members—Mr John Henderson.

Mr Henderson briefly replied, and in return wished all health and prosperity to the Geological Society of Glasgow.

XXV.—*Excursion to Fife Coast.* Mr JOHN HENDERSON, *Leader.*

22d July.

The party proceeded from Aberdour eastwards towards Burntisland, examining the various sections exposed along the seashore. At Starlieburn a recent and local stalagmitic deposit formed by a spring rising out of the Starlieburn limestone was specially noted. The party then examined the sections exposed in the Grange Quarries.

XXVI.—*Excursion to the Suburban Railway Works.* Mr R. A. F. A. COYNE, *Leader.*

29th July.

These most interesting sections were examined in detail.

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XXVII.—*Meeting of Northern Scientific Societies at Inverness on 11th and 12th August* 1882.

Delegates—

WILLIAM FERGUSON, Esq. of Kinmundy, F.G.S., F.L.S., *Vice-President.*

RALPH RICHARDSON, Esq., W.S., F.R.S.E., *Vice-President.*

W. IVISON MACADAM, Esq., F.C.S., F.I.C., *Honorary Secretary.*

The first meeting of the Northern Societies was held last year at Elgin. This year these Societies, seventeen in number, including the Edinburgh Geological Society, assembled at Inverness, Mr Thomas D. Wallace, rector of the Inverness High School, being again Convener and Secretary. The Edinburgh Geological Society was represented by Mr Ralph Richardson, vice-president; Mr William Jolly, H.M. Inspector of Schools; Dr Semple; Mr James Fraser, C.E., Inverness; and Mr Thomas D. Wallace. The members of the various Societies assembled at seven o'clock on the evening of Friday, 11th August, in the beautiful new Town Hall of Inverness. They then adjourned to the Castlehill, from which a distant prospect is obtained. Mr Jolly pointed out the objects of geological, and Mr Alex. Ross, architect, Inverness, those of archæological interest. Then the company returned to the Town Hall, where the reading of papers began at eight o'clock, under the presidency of Mr Kenneth Macdonald, President of the Inverness Scientific Society and Field Club, which made all the arrangements for the meeting. The Town Hall was well filled, and many ladies were present. Sheriff Blair, Inverness, Professor Struthers, Aberdeen, Mr Forbes of Culloden, and others occupied seats on the platform. The following papers were read:—(1) Inverness in the 18th Century, by Mr Kenneth Mackenzie; (2) Craig Phadrick—Distribution and Theories of Vitrified Forts, by Dr Thomas Aitken, Inverness; (3) Old Inverness, by Mr Alex. Ross; (4) Life in the Highlands in the Olden Time, by Mr William Mackay, solicitor, Inverness; (5) Origin of the Andalusite Schists in Banffshire and Aberdeenshire, by Mr John Horne, of H.M. Geological Survey, Huntly; (6) The Arctic Shell-Beds of Scotland, by Mr Ralph Richardson; (7) The Salmon, with Observations on the Improvement of our River Fishings, by the Rev. W. Chisholm, Banff. At the conclusion of the Meeting it was resolved, on the motion of Mr John Horne, seconded by Mr Alex. Ross, that the Societies should meet next

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year in Banff. Most of the company afterwards supped together in the Station Hotel, Mr Kenneth Macdonald presiding, when numerous toasts were honoured.

On the morning of the 12th August, ninety members of the various Scientific Societies left Inverness in carriages for an excursion. The weather was magnificent. Passing Clachnaharry and the Well of the Nymphs, the route lay along the southern shore of the Beauly Firth to Kirkhill. Mr Jolly explained the geology, and Mr Wallace the archæology of the district at one stoppage, whilst at Kirkhill Mr James Barron, of the *Inverness Courier*, gave a graphic account of the history of the Lovat family. The company inspected the chapel which is the burial-place of several distinguished members of the Fraser clan. Not long afterwards Tarradale was sighted, where Sir Roderick Murchison was born in 1792, and then the excursion party drove into Beauly. Arriving at Beauly Priory, Mr Ross, architect, minutely described the ruins, which are of much interest. The party then drove along the northern bank of the Beauly river to the splendid Falls of Kilmorack, where luncheon was generously provided by Sheriff Blair and Mr Kenneth Macdonald. Still proceeding along the north bank of the Beauly, surrounded by most romantic scenery, the party reached Struy, where the Silurian rocks take the place of the Old Red conglomerate. Considerable time was spent at a cliff of mica schist, where fine specimens of mica and some beryls and garnets were found. The route home was along the southern bank of the river to Beaufort, Lord Lovat's residence, the grounds of which his lordship kindly threw open to the party. They went all over the magnificent new castle which is being erected by his lordship, and which closely adjoins his quaint old residence. Before leaving Beaufort, Mr Ralph Richardson, in name and at the request of the members of the other Scientific Societies represented, thanked the members of the Inverness Scientific Society and Field Club for the day of enjoyment which had been passed, the success of which was largely due to the admirable arrangements made by the Inverness Society. The party reached Inverness about 10 P.M., after twelve hours spent amid some of the finest scenery in the Highlands.

XXVIII.—*British Association Meeting at Southampton, September* 1882.

Delegates—

CHARLES LAPWORTH, F.G.S., Professor of Geology, Mason Science College, Birmingham.

W. IVISON MACADAM, F.C.S., F.I.C., Lecturer on Chemistry, *Honorary Secretary.*

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APPENDIX.

PAPERS READ BEFORE THE EDINBURGH GEOLOGICAL SOCIETY DURING SESSION 1881-82.

17th November 1881 (47th Anniversary Meeting).—1. Inaugural Address. By D. Milne-Home, Esq. of Milnegraden, LL.D., *V.-P.* R.S.E., *President*.—2. Reports by the Secretary and Treasurer.—3. Notice of Clayshell Bed at Clava. By James Fraser, C.E., Inverness. —4. Notice of Shell Bed at Fort George. By Thomas D. Wallace, F.S.A. Scot., Inverness. Communicated by the *Honorary Secretary*.

15th December 1881.—1. Notes on a Sand Covered District on the East Coast of Aberdeenshire. By William Ferguson, Esq. of Kinmundy, F.R.S.E., F.G.S., &c., *Vice-President*.—2. The Irish or Western portion of Dr A. Geikie's "Lake Caledonia Basin" of the Lower Red Sandstone. By G. H. Kinahan, M.R.I.A., Geological Survey of Ireland. Communicated by the *Honorary Secretary*.—3. The Glaciers of Lower Strathnairn. By David Cameron, Daviot.—4. Note on Fossiliferous Strata, Lower Strathnairn. By David Cameron. Communicated by the *Honorary Secretary*.

19th January 1882.—1. Further Observations on Kammplatten. By Thomas Stock, Museum of Science and Art.—2. The Geology of Pic de Saucy Mountains, France, illustrated by Minerals and Diagrams. By Dr W. T. Black.—3. Analysis of Laterite from Huranbee, Pegu. By Dr R. Romanis, Rangoon. Communicated by the *Honorary Secretary*.—4. Analyses of Coals from New Zealand and Labuan. By W. Ivison Macadam, F.C.S., F.I.C.—5. Exhibition of Fossil Decapod Crustaceans from Eskdale. By Thomas Stock.

27th January 1882 (Special General Meeting).—1. Motion by Mr H. M. Cadell as to the Society's Museum.—2. Alterations of the Laws and Bye-Laws of the Society consequent on Mr Cadell's Motion.—3. Other Alterations on the Laws and Bye-Laws of the Society. Notice given by Mr W. Ivison Macadam.

16th February 1882.—Historical and Geological Sketch of the Silurian Districts of South Lanarkshire. By John R. S. Hunter, LL.D., D.Sc., &c., Carluke. *A very large and interesting collection of Fossils was exhibited.*

16th March 1882.—1. Remarks upon the Geological Formations of New Zealand. By J. Coutts Crawford, Esq. of Overtoun, Resident

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Magistrate and Sheriff of Wellington, *Foreign Corresponding Fellow.* Communicated by the *Honorary Secretary.*—2. Additional Notes on the Geology of the North-East Coast of Norfolk. By Wm. R. M'Dairmid.—3. Account of the Mount Bischoff Tin Mines, New Zealand. By Ed. M'Glashan, *Foreign Corresponding Fellow.* Communicated by the *Secretary. Illustrated by Specimens.*—4. The Glacial Phenomena of Athole, by David Cameron, Daviot. Communicated by the *Secretary.*—5. Note and Exhibition of a variety of Saponite, found by Mr William Burns, Glasgow Geological Society, in the Cathkin Quarry. By W. Ivison Macadam, F.C.S., F.I.C. *Specimens.*

20*th April* 1882.—1. On the Granite Quarries of Kinmay, Aberdeenshire. By Wm. Ferguson, Esq. of Kinmundy, F.R.S.E., F.L.S., &c., *Vice-President.*—2. On the Discovery of Arctic Shells at High Levels in Scotland. By Ralph Richardson, W.S., F.R.S.E., *Vice-President.*—3. Notes on some Geological Formations in the Neighbourhood of Ballater. By Wm. Hamilton Bell.—4. On the Analysis of a Sample of a White Deposit from the Peat of Aberdeenshire. By W. Ivison Macadam, F.C.S., F.I.C., *Honorary Secretary.*

4*th May* 1882.—1. On some Marine Beds underlying the Gilmerton Limestones. By John Henderson.—2. Note on the Occurrence of Decapod Crustacean Remains in the Wardie Shales. By Thomas Stock, Natural History Department, Museum of Science and Art.—3. Additional Notes on the Surface Geology of the Estuary of the Forth. By H. M. Cadell, B.Sc.—4. Notes on the Glaciation of Scotland and Norway. By H. M. Cadell, B.Sc.—5. Further Notice of the Tigh-na-criche Shell Bed. By W. Ivison Macadam, F.C.S., F.I.C., *Honorary Secretary.*—6. On the Origin and Age of Quartz Veins in the Strata in the Neighbourhood of Falmouth. By Alex. Somervail, *Associate.* Communicated by the *Honorary Secretary.*—7. Valedictory Address for 48th Session. By Wm. Ferguson, Esq. of Kinmundy, *Vice-President.*

SUMMER EXCURSIONS OF THE SOCIETY.

1882.

1. 10th June. Oakbank Shale Pits and Paraffin Oil Works. *Leaders*, Messrs Calderwood and Mitchell.
2. 17th June. Pentland Silurians. *Leader*, Mr John Henderson.
3. 1st July. Joint Excursion with Glasgow Geological Society to Carluke, to visit Sections, and also Dr J. R. Hunter's Museum. *Leader*, Dr Hunter.
4. 22d July. Fife Coast from Aberdour to Burntisland. *Leader*, Mr Henderson.
5. 29th July. Edinburgh Suburban Railway Cuttings. *Leader*, Mr R. A. F. A. Coyne.
6. 11th and 12th August. Joint Meeting of Northern Scientific Societies at Inverness.

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TRANSACTIONS

OF THE

EDINBURGH GEOLOGICAL SOCIETY,

SESSION 1882-83.

I.—*Inaugural Address, Session* 1882-83. By RALPH RICHARDSON, W.S., F.R.S.E., *Vice-President.*

(Read 16th November 1882.)

GENTLEMEN,—We are met to-night once more to celebrate the Anniversary of our Society. It was founded so long ago as 1834 by a band of enthusiastic Huttonians. As you are aware, there was once a stout strife in the geological world between the followers of the German geologist Werner, and those of the Scottish geologist Hutton. Werner and his able disciple, Prof. Jameson of Edinburgh, gave the peculiar ideas of their school world-wide celebrity for a time. But our distinguished fellow citizen, James Hutton, proved by the study of the rocks of this very locality, that the doctrines of Werner were, in many instances, erroneous. The battle, as I have said, waged loud and long, but at last Hutton and the Huttonians remained masters of the field. The once flourishing Wernerian Society of Edinburgh drooped and died; and the Edinburgh Geological Society, founded by some of the victorious Huttonians, was called into being in 1834, and has flourished ever since.

I need only point to the work done by our Society during the past session to prove that it is in a healthy and flourishing condition. It fulfilled, during last session, the *three* functions which I consider every healthy Geological Society should perform, viz.,

1st. It held frequent *Meetings* for the reading of papers and the discussion of geological topics.

2d. It published *Transactions* containing most of the papers read at these Meetings; and

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3d. It took part in numerous *Field Excursions* to districts of geological interest, which were carefully examined under the guidance of competent leaders.

All this our Society has done; but let it never forget to award a due meed of applause to its able, energetic, and painstaking secretary, Mr Ivison Macadam, who has truly been the mainspring of the Society, and to whom I am sure you will allow me to take this opportunity of expressing the hearty thanks of the Society for his devotion to its interests during the past year.

Permit me now to proceed with my inaugural address. I have taken a subject familiar to you all, and abundantly illustrated by the rocks of our own district. I have linked with that subject the name of its greatest exponent, a name honoured and revered by every student of science.

Thanks to James Hutton, the solid rocks which form the frame-work of the globe had been classified and arranged. Their aqueous or igneous origin had been recognised; their fractures, faults, synclines, and anticlines had been studied and understood. There still remained, however, a wide field for exploration, and no light for long illuminated it. What were men to make of that vast accumulation of clay, sand, gravel, and rock débris which lay upon the solid strata of the globe, and in many places obscured these strata entirely from view? This huge mass of loose and evidently travelled material puzzled and amazed humanity. Unscientific persons of course lent their aid in solving the riddle. They said it was the remains of the Noachian Deluge. Geologists had nothing to say, so did not controvert the others. Consequently the great superficial mass acquired the name of *Diluvium*, that is to say, the result of water sweeping the earth, and leaving a sad jumble of clay, sand, gravel, and rock débris behind.

The unscientific theory thus advanced gave an immense importance to the Noachian Deluge, for it carried it to almost every man's door, as, according to this theory, he could see the effects of the Deluge all around him.* But a young Swiss naturalist proved this theory to be all wrong. British geologists had not the advantages of study which he enjoyed. They had not glaciers in their country. They could not see and study the effect of the passage of ice over rocks, and they could not realise the motive power of ice. Certainly they had come very near the truth. Our great fellow citizen, Playfair, in his "Illustrations of the Huttonian Theory," had so long ago as 1802 pointed

* Mr Milne-Home mentions in his valuable book on "Ancient Water Levels" (1882, p. 76), that, within a very recent period, an English gentleman, observing immense beds of stratified sand and gravel at the height of 1190 feet on a Scottish hill, exclaimed, "Surely Noah's flood has been up here!"

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out that glaciers are by far the most powerful engines which Nature employs for the moving of large masses of rock. But this was only an isolated passage in the Scottish philosopher's work, a mere *obiter dictum*, and although highly creditable to his perception, led to no important result. The world waited for a man to unfold the mystery of its superficial geology, and in Agassiz it found him.

Louis John Rudolph Agassiz was born in the parish of Mottier, near Lake Neuchatel in Switzerland, on 28th May 1807. "He was," says the Rev. Dr Rufus Stebbins, "of Huguenot descent, and his ancestors were driven from France by the revocation of the edict of Nantes. For six generations his lineal ancestors had been clergymen."* Throughout his whole life he retained a firm belief in the revelations of Christianity, and, like Hutton, his greatest satisfaction in his scientific researches was to discover anything calculated to impress upon humanity more clearly the greatness and goodness of God. His turn for natural history was early exhibited at the elementary school of Bienne, where he observed the habits of fishes and collected insects. He entered the University of Lausanne at the early age of fifteen, or one year older than the age at which Hutton entered the University of Edinburgh. After studying for two years at Lausanne, he went to Zurich to study medicine. At the age of nineteen he entered the University of Heidelberg, and studied under celebrated professors, anatomy, physiology, zoology, and botany. Like Hutton, he was destined for the medical profession, but, like him, he was too restless to settle down to practise. He went to the University of Munich, after being only a year at Heidelberg, and he remained there for four years, attaining great distinction by his researches. In particular, his first work, a folio in Latin on the classification of the fishes of Brazil, a country which he was destined to visit at the height of his fame many years later, gained him great celebrity. He graduated doctor of philosophy at the University of Erlangen, and doctor of medicine at the University of Munich, and devoted himself heart and soul to scientific research. No one could be more energetic, brilliant, or painstaking in his observations, and as a result he rapidly won a foremost place among the men of science of the world.

It was in 1836, when he was twenty-nine years old, that Agassiz resolutely set himself to study the glaciers of the Alps, and his celebrated work, *Etudes sur les Glaciers*, was published at Neuchatel in 1840, accompanied by an atlas with plates illustrating the glaciers. The work likewise appeared in German, being published at Solothurn (Solerne) in 1841. Its appearance

* Report of Smithsonian Institution, Washington, 1874, p. 199.

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marks an epoch in the history of superficial geology, for until Agassiz cast light upon the subject by his researches, men had groped about very much in the dark. SCHEUCHZER, the eminent Zurich naturalist, had in 1706 described the glaciers, but did not remark their moraines or polished rocks. GRUNER in 1760 made interesting observations on the movements of the Grindelwald glaciers. In 1803 DE SAUSSURE laid the foundations of our present knowledge of glaciers, and was the first to remark their moraines. He observed likewise the polished rocks, which he named *roches moutonnées*, but he erroneously attributed the polishing to water. So also Sir JAMES HALL, the eminent Scotch physicist, attributed in 1812 (after visiting the Alps) the polishing of the *roches moutonnées* of Corstorphine Hill near our city to "the operation of immense torrents of water." I read a paper upon this subject before our Society in March 1875, after visiting Switzerland and Savoy,* and pointed out the resemblances between the *roches moutonnées* of Corstorphine Hill and polished rocks which I had seen near the Handeck in the upper portion of the Hasli Thal.† HUGI in 1830 narrowly studied the Swiss glaciers, but, strangely enough, he considered the *roches moutonnées* a peculiar form of weathering assumed by granite. In 1833 VENETZ suggested the vast extension of the Alpine glaciers in former times, and instanced the remains of old moraines as evidence. His friend CHARPENTIER studied the little glacier lakes, and was the first to recognise that glaciers abrade, round, and polish the rocks they traverse. It was with him that Agassiz spent five months in 1836, deriving immense benefit from his experience during the frequent excursions which they made among the Alps to study glaciers and glaciercation. Indeed, Agassiz dedicates his great work the *Etudes* to Venetz and De Charpentier, stating that their important researches had aroused in him a desire to study the glaciers of the Alps, whilst their kindness had enabled him to study them thoroughly. In 1837 Agassiz, as President of the Swiss Society of Naturalists assembled at Neuenberg, detailed in his inaugural address the result of his glacial researches, and in 1838, after visiting the glaciers of the Bernese Oberland and of Chamonix, he read a paper before the Geological Society of France, in which he particularly referred to the polished rocks of the Hasli Thal as the most remarkable he had yet seen.‡ Finally, he went in 1839 with STUDER and other friends again to the Bernese Oberland and elsewhere, studying the great moraines of the Kandersteg, the expanse of "Karrenfelder" on the Gemmi, the Valley

* "Transactions," vol. iii. p. 31.
† Diagrams of both accompany my paper cited *supra*, p. 33.
‡ Described and figured in paper last cited.

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of the Visp, and the remarkable glaciers of Zermatt.* After all this long and careful preliminary research, he felt qualified and entitled to write a book, and so his famous *Etudes sur les Glaciers* appeared, bearing a preface dated from the lonely glacier-surrounded "Grimsel Hospice, 20th August 1840,"—6100 feet above the sea level.

How many great minds have felt impelled to investigate these huge "rivers of ice," the glaciers of the Alps! I have mentioned former workers in this field, and the race is not extinct. The lamp of De Saussure was transmitted to Agassiz, and handed down by him to that great Scottish physicist, the late Principal James D. Forbes,† and that distinguished English natural philosopher, Professor Tyndall. Both the latter have published works of great importance upon the subject of glaciers, Forbes' "Travels in the Alps of Savoy" appearing in 1855, whilst Tyndall's work on the "Glaciers of the Alps" was published in 1860, and his charmingly written "Forms of Water" appeared in 1872. In the case of all these eminent men of science, they had devoted lengthened periods of time to living beside the glaciers, chronicling from day to day their minutest movements, and carefully observing their structure. They endured willingly great personal hardships for the cause of science, living among frost and snow at immense altitudes for weeks and months at a time, and undertaking journeys of a daring and fatiguing description in order to verify their observations. Mr Whymper's beautifully illustrated work, "Scrambles amongst the Alps," published in 1871, gives us some idea of the dangers, as well as delights, experienced among their treacherous snows.

Agassiz had undergone all this hardship for years before he ventured to systematise his observations. His *Etudes sur les Glaciers* represent field work done by him at much personal risk and trouble from 1836 to 1840. The treatise is divided methodically into, first, an historical retrospect which I have briefly sketched above; then he describes the general phenomena of glaciers; next, the structure of glaciers; then the appearance of glaciers; fifthly, the colour of glaciers: sixthly, the crevasses in glaciers; seventhly, the glacier needles or pyramids (*Gletscher nadeln*); eighthly, the moraines; ninthly, the glacier pillars or tables (*Gletscher tische*); tenthly, the

* Described and figured in author's paper on "The Alps of Switzerland and Savoy," printed in vol. iii. of the Society's "Transactions," p. 11.

† On 21st January 1869, Dr Archibald Geikie, then President of our Society, read an admirable obituary notice of Principal Forbes, an honorary Fellow, detailing his life-long scientific labours. He was appointed Professor of Natural Philosophy in Edinburgh University when only twenty-four years of age. He died in December 1868, when Principal of the United College of St Salvator and St Leonards in the University of St Andrews.—"Transactions G. S. E.," vol. i. p. 238.

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gravel cones (*Schutt Kegel*); eleventh, the formation of glaciers; twelfth, the movement of glaciers; thirteenth, the appearance of the ice from beneath glaciers; fourteenth, the action of glaciers on the rocks they traverse; fifteenth, the temperature of glaciers and of their bed, and the water and atmosphere in their vicinity; sixteenth, the oscillation of glaciers in historical times; seventeenth, the previous extension of the glaciers of the Alps; and eighteenth, the evidence of the existence of great ice-fields beyond the region of the Alps. The work, as I have said, is accompanied by an atlas containing beautiful sketches illustrative of glacier phenomena. A more detailed treatise by Agassiz, assisted by Messrs Guyot and Desor, appeared at Paris in 1847 under the title, "Systeme Glaciare ou recherches sur les Glaciers," and was likewise illustrated by an atlas.

From a geological point of view, we need not do more than consider a few of the phenomena treated of in these important works. Questions relating to the origin, structure, and movements of glaciers obviously belong to the province of physics rather than of geology. But there are other questions discussed in these works which most materially concern the student of the surface-geology of the world. He finds in them a key to unlock a mystery which for centuries had remained unsolved. This was, stated briefly, that a large portion of the world was once subjected to a glacial epoch such as is still known in the higher regions of the Alps, and that the same phenomena which are there displayed were once, over a wide area, called into active existence. The evidences of ice having formerly traversed districts now far removed from its influence seemed to Agassiz clear, and furnished in his hands the explanation of a large portion of the surface-geology of the globe. The ancient moraines were attributed by him to ancient glaciers. The erratic blocks strewed along the slopes of the Jura told him of the former extension of the ice there. The *roches moutonnées* in every Alpine valley proved to him that it had once been traversed by a glacier which rounded, polished, and striated its rocks as it passed slowly over them. Thus from one glacial centre, the Alps, he saw a large portion of Europe affected by glaciers which are now shrunk into the mere shadows of their former selves.

It is not difficult to see how Agassiz, after discovering that Switzerland generally had in former times been subject to the passage of ice, should extend his researches beyond the Swiss frontier and find similar traces of ice in countries far removed from existing glaciers. But he obtained other than physical proofs of this. Elie de Beaumont, the famous French geologist, had ascertained that the "Diluvium" of the neighbourhood of Lyons, in which he had discovered elephant remains, was precisely

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similar to the Diluvium of the north of Europe, which latter Diluvium was the product of ice action, and contained similar elephant remains. Agassiz therefore arrived at the conclusion that an "ice-sheet had once covered the entire surface of Europe, with the exception of some of the higher mountain peaks." *

This then is the great theory of Agassiz, and with it he closes his famous treatise. The extent of the ice-sheet in Europe has been modified by later observers, and the maps by Habenicht † and Dr James Geikie ‡ do not represent the glaciated area of Europe at the climax of the ice age as extending further south than the 50th line of latitude, with the exception of the mountainous regions of the Alps, Pyrenees, Carpathians, and Caucasus. But in all its broader features the glacial theory of Agassiz remains as it was announced in 1840. It has led to many a fierce battle between the glacialists and antiglacialists, reminding us of the old frays between the Plutonists and Neptunists, the Huttonians and Wernerians. The disciples of Agassiz have zealously carried his ice-sheet to every quarter of the globe. Its very height and depth have been gauged. In Scotland, it is stated to have attained a thickness of 3000 feet. In America, an enthusiastic disciple demands for it a thickness of 12,000 feet, whilst Agassiz himself, as we shall find further on, modestly stated it at 6000 feet from evidence in the vicinity of Mount Washington. Probably no province of geology has proved more attractive to the general public. In fact, it may be said that Agassiz's ice-sheet has given new life to geology, for it has furnished the geological lecturer with many a thrilling tale with which to arouse the interest and enthrall the imaginations of his audience. As I remarked before, the evidences of the glacial epoch lie around every man's door, they appeal to every mind, and in the hands of a skilful speaker or writer may be made so attractive as to hold hearer or reader spellbound.

It will be remembered that the *Etudes sur les Glaciers* were launched from the Grimsel Hospice in August 1840. The very next month we find Agassiz at the meeting of the British Association which was held at Glasgow, and to attend which Murchison had travelled from Nijni Novgorod in Russia. This meeting was remarkable as having brought into notice two Scottish geologists destined to become celebrated, viz., Hugh Miller and Andrew Crombie Ramsay, lately Director-General of the Geological Survey. The fame of Agassiz had long before been recognised, but in a palæontological field. He was *facile princeps* in the department of fossil fishes. Murchison writes to

* "Etudes sur les Glaciers," chap. xviii.
† Petermann's "Geographische Mittheilungen," 1878. Tafel 6.
‡ "Prehistoric Europe," 1881.

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Sedgwick: "Agassiz's arrival was very opportune, for he confirmed the identification of the Russian and Scottish fishes. I also resolved to pull out Hugh Miller of Cromarty, and other Scotsmen of the north, and on the last day I gave an *exposé* of all that you and myself did in the beginning of this foray, and held up our sections and our *Dipteri*. Agassiz followed, and ended by naming the curious new winged creature *Pterichthys Milleri*." *

Then Murchison continues: "Agassiz gave us a great field day on glaciers, and I think we shall end in having a compromise between himself and us of the floating icebergs! I spoke against the general application of his theory." The truth is, it was neither fossil fish nor the British Association which specially brought Agassiz to Scotland. On the contrary, as he tells us in his "Geological Sketches," to which reference will presently be made, Agassiz visited Britain in 1840 "with the express object of finding traces of glaciers;" or, as Mr James Smith of Jordanhill expresses it in his classic *Researches*, "with the object of searching for proofs of the former existence of glaciers in that country, and their connection with erratic blocks." † For this purpose he seems to have scoured Scotland in every direction. An English geologist who had been "frost bitten," as Murchison termed it, by the glacial theories of Charpentier and Agassiz, the Rev. Prof. Buckland, D.D., had, after visiting Agassiz in Switzerland in 1838, and hearing his glacial views, gone over the ground in Britain before, and had satisfied himself of the application to it of the lessons of the Alps. Agassiz confirmed Buckland's observations, and announced that the ice-sheet which he had described in his *Etudes sur les Glaciers* must have covered the greater part of Britain. This raised a tempest in the geological camp. Murchison and other leaders flatly refused to believe so novel and startling a theory. They seem to have had no objection to icebergs floating over Scotland, but as to its having been enveloped in a *mer de glace*, they scouted the notion as absurd.

To return to Agassiz's rambles in Scotland. He visited Edinburgh, where he met an eminent local geologist who, like Hugh Miller, wielded the pen of a newspaper editor as well as the hammer of the geologist. This was the President of our Society, Charles Maclaren, editor of the *Scotsman*, and author of one of the most faithful handbooks ever written on the Geology of Fife and the Lothians. Maclaren took Agassiz to Blackford Hill, near Edinburgh, in November 1840, whereupon,

* Dr Archibald Geikie's "Life of Murchison."

† Page 127, being paper read by Mr Smith before the Geological Society of London, 4th June 1845.

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on entering Blackford Quarry, and observing a striated cliff, Agassiz instantly exclaimed, "That is the mark of the ice." Writing in 1873, Mr George A. Panton, then the Librarian, but long the esteemed Secretary of our Society, says in our "Transactions" * regarding this striated cliff:—"The striæ are well marked and quite distinct, and a considerable portion of the surface is covered with groovings." Maclaren confesses that, like Mr Smith of Jordanhill, he had long felt a difficulty in accepting Agassiz's glacial views, but ultimately he yielded. The *debâcle* theory, the iceberg theory, the local glacier theory, had, and still have, their champions; but certainly the tendency among geologists, especially those connected with the Geological Survey of Scotland, is to accept Agassiz's theory *pur et simple*, and to believe that, as he said in 1840, a large portion of "Europe was once covered by a vast ice-sheet," and that much of the superficial geology of Europe is due to the movements of that ice-sheet. Geologists in other parts of the world bear similar testimony. They tell us that a great portion of the North American continent shows the marks of an ice-sheet. In Asia, too, a large portion of that continent seems to have been once buried in ice. Australasia and even Africa appear to tell the same tale. Thus arose that theory advanced in 1864 by our celebrated fellow-citizen, and esteemed member of our Society—Dr James Croll—that the world has, owing to astronomical causes, seen several glacial epochs, and that they occur periodically; whilst Sir Andrew Ramsay maintains that ancient geological formations show traces of glacial epochs in the polished rocks they contain. All this has whetted and stimulated the popular imagination. The idea that our globe is slowly but surely approaching a period when our sunny valleys and smiling fields will be buried for centuries thousands of feet deep in ice and snow, arouses the same excitement as would the approach of a comet, which prophets declared would make the world uninhabitable on account of heat. But all this excitement has been a gain to geology. The story of the glacial epoch has equipped and rewarded many a geological lecturer and writer. It has fascinated multitudes to whom rock systems are uninteresting and fossils are uninviting. It has converted geologists into orators and poets; for I have invariably observed that when a geologist begins to descant upon the wonders of the glacial epoch, he leaves sober prose for eloquence and poetry. Glacial geology has, as I have said, given new life to geology, and, owing to the complicated character of its phenomena, will afford room for doubts and battle for many long years to come.

* Vol. ii. p. 238.

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The leading living exponent of the theory of Agassiz is our eminent honorary fellow, Dr James Geikie, whom we were so glad to welcome this year to our city as Professor of Geology, in the University of Edinburgh. His work, "The Great Ice Age," * has popularised and illustrated the theory to a greater extent than it probably ever was before. Dr Geikie's able colleagues in the Geological Survey of Scotland seem all to subscribe to the same tenets, and two, Messrs Peach and Horne, have recently illustrated the ice-sheet theory by reference to the superficial geology of Caithness, Orkney, and Shetland.† Yet there is another camp of geologists who will have none of the theory of Agassiz. Led by those distinguished geologists, also both Scotsmen, the present Duke of Argyll, the Patron of our Society, and our esteemed President, Mr Milne-Home of Milnegraden, this hostile array numbers several names of note in the geological world. In his presidential address to our Society, in November 1876,‡ Mr Milne-Home told us how the British Association had met at Glasgow during the previous September, and how, in the geological section, only one geologist (Professor Williamson) had a good word to say for Agassiz's ice-sheet theory. The Duke of Argyll, in the course of a discussion on a paper which he had read on the "Physical Structure of the Highlands of Scotland," said :—"I disbelieve altogether in the theory of what is called an *ice cap*, or in other words, hold that there is no evidence that there ever existed any universal mantle of ice higher or deeper than all the existing mountains, covering them, and moving over them from distant northern regions." His Grace attributed the denudation done during the glacial period simply to ice in the three well-known forms of *first*, true glaciers, descending mountain slopes; *second*, icebergs detached from the termination of these glaciers where they reached the sea; and *third*, by floe or surface ice driven by currents, which were determined in direction by the changing contour of the land during the processes of submersion and re-elevation. Mr Milne-Home added that Dr Archibald Geikie, now Director-General of the Geological Survey, in referring to the great value of his Grace's paper, "stated that he was prepared to endorse almost every word of it. As to the ice-sheet, he quite agreed that there had been no geological change sufficient to account for the presence of the enormous mass of ice which was sup-

* A second edition appeared in 1876, three years after its first issue.

† Their papers on Glaciation are as follows :—*Caithness*—"Pro. Royal Phys. Soc. Edin.," vol. vi. (1881). *Orkney*—"Q. J. G. S.," London, Nov. 1880. *Shetland*—"Q. J. G. S.," Nov. 1879, and "Geol. Magazine," Feb. and Aug. 1881 (in reply to Mr Milne-Home's criticisms in his address to our Society in May 1880, "Transactions," vol. iii. 1881).

‡ "Transactions," vol. iii. p. 99.

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posed by some to have covered the northern hemisphere." Mr Milne-Home observes that after such expressions of opinion regarding the ice-cap by these eminent authorities, "we shall probably hear little more of that theory in Scotland." A second edition, however, of Dr James Geikie's "Great Ice Age" was called for that very year; and as to Dr Archibald Geikie's views, reference may be made to a paper originally read by him before the Royal Society of Edinburgh in 1866, but republished in his "Geological Sketches" in 1882, in which he states, after a visit to Norway, that "this short excursion into the northern part of Scandinavia furnished us with abundant proofs that the glaciation of the west of Norway was produced by a mass of land ice, of which the present glaciers are the representatives. It likewise confirmed, in a most impressive way, the conclusion which has gained ground so rapidly within the last few years, that the glaciation of the Scottish Highlands, as well as of the rest of the British Isles, is, in the main, the work not of floating bergs, but of land ice. This conclusion may, indeed, be regarded as demonstrated beyond all cavil by the ice marks of Norway." Further, in his "Text Book of Geology," published this month, Dr Archibald Geikie states (p. 885) that "at the base of the glacial deposits, the solid rocks over the whole of Northern Europe present the characteristic smoothed flowing outlines produced by the grinding action of land ice," adding (p. 887) "that the ice is computed to have been at least between 6000 and 7000 feet thick in Norway, measured from the present sea level." At the meeting of the British Association, held at Glasgow in 1876, as at the meeting held there in 1840, at which he was himself present, the ice-sheet theory of Agassiz met with an unfavourable reception. Time will show whether he or his opponents are right. Meanwhile there is no doubt that the younger school of geologists, in every part of the globe, are ranged as a rule on the side of Agassiz.

The exceedingly interesting and instructive life of Agassiz has not yet been written, although it is understood that his son has been for some years engaged upon it. Short memoirs, however, of so illustrious a man of course abound, one of the best being by Mr Dallas, assistant Secretary of the Geological Society of London, which precedes the presidential address delivered by the Duke of Argyll in February 1874. But perhaps as interesting a memoir as any is an autobiographical one by Agassiz himself, which may be gathered from various papers contained in the second series of his "Geological Sketches." Both series were published at Boston, in the United States of America, which Agassiz made his home from 1846 till his death in 1873.

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The *first* series appeared in 1866, and contained ten sketches, three descriptive of glaciers, viz., their formation, their internal structure and progression, and their external appearance; besides various other papers. This volume likewise contains a portrait of the author, representing him as a massive-faced, healthy, good-humoured man of Teutonic type, with lofty brow, large mouth, and long hair. In the Rev. Dr Stebbin's admirable memoir,* he refers to the "most winning and commanding presence" of Agassiz having of itself made an impression on his arrival in America. The *second* series of "Geological Sketches" appeared in 1876, and contained the following papers, which, like those in the previous volume, had mostly appeared in the pages of the *Atlantic Monthly*:—

1. Glacial Period.
2. The Parallel Roads of Glen Roy in Scotland.
3. Ice Period in America.
4. Glacial Phenomena in Maine.
5. Physical History of the Valley of the Amazon.

Here was ice with a vengeance! The heart of the coldest glacialist must warm towards such a book. The last paper was founded upon a visit undertaken by Agassiz and his wife to Brazil, an account of which was published at Boston in 1868 under the title of "A Journey in Brazil," by Professor and Mrs Louis Agassiz. In Brazil, as in Switzerland, Britain, and the United States, Agassiz satisfied himself that glacial phenomena abounded, and that the valleys bore evidence of having once been traversed by glaciers, as glacier drift, *roches moutonnées*, and boulders were apparent in various directions. "O meu padre!" was the exclamation of a Brazilian as he introduced Agassiz to his parish priest, "O meu padre! here is a wonderful worker of miracles. He can fill these valleys with ice, he covers the mountains with snow in the hottest days, he brings the stones from the top of the serra to the bottom, he finds animals in the bowels of the earth and brings out their bones." "Ah!" replied the padre, "he is a wonderful saint, truly! He is such an one as I need for my chapel."

Let us run rapidly through the sketches in the second series which I have already enumerated, in order to gain an insight into Agassiz's career as a glacialist after leaving Switzerland. He commences his first sketch, the "Glacial Period," with the following words:—"In the early part of the summer † of 1840 I started from Switzerland for England with the express object

* "Smithsonian Report," 1874, p. 202.

† This should apparently rather be "autumn," as his preface to the *Etudes sur les Glaciers* is dated from the Grimsel Hospice on 20th August 1840. He attended the British Association meeting in Glasgow in September 1840.

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of finding traces of glaciers in Great Britain. This glacier-hunt was at that time a somewhat perilous undertaking for the reputation of a young naturalist like myself, since some of the greatest names in science were arrayed against the novel glacier theory." The "greatest geologist in Europe,"* he says, "formally announced the demise of the glacial theory. Since then it has risen, phœnix-like, from its own funeral pile." Many of his friends in England implored him to give up his wild glacier-hunt. The satirical organs even took up the question. "*Punch* himself did not disdain," he says, "to give me a gentle hint as to the folly of my undertaking, terming my journey into Scotland in search of *moraines* a sporting expedition after moorhens." Only one of his older scientific friends in England, "a man who in earlier years had weathered a similar storm himself," encouraged and accompanied him. This was the Rev. Dr Buckland, whose personal acquaintance Agassiz had made in 1834, when, engaged in the investigation of fossil fishes, he had travelled with him through parts of England and Scotland. As I mentioned previously, Buckland visited Agassiz in Switzerland in 1838, and when there Agassiz drew his attention to the action of ice as producing polished, striated, and furrowed surfaces on the Jura, thus enabling him, on his return to Britain, to apply the glacial theory to British rocks, and to dismiss the diluvial theory which he had formerly entertained.† Thus Buckland, guided by Agassiz, had been the first to introduce the glacial theory to Britain, and he welcomed the arrival of the young philosopher in 1840. After the meeting of the British Association in Glasgow to which I have already referred, Agassiz and Buckland, undeterred by the coolness with which the new theory had been received there, "started for the mountains of Scotland in search of glaciers, which," says Agassiz, "if there was any truth in the generalisations to which my study of the Swiss glaciers had led me, must have come down from the Grampian range and reached the level of the sea as they do now in Greenland."

The result, in scientific language, of their tour will be found in a paper read by Agassiz before the Geological Society of London on 4th November 1840.‡ Agassiz did not confine his researches to Scotland, but extended them through the north of England, and the north, centre, west, and south-west of Ireland. The conclusion at which he arrived was that "great masses of

* Probably Leopold von Buch is here referred to. Von Buch wrote to Sir R. Murchison inveighing against the glacial theory which he said had passed over Germany like "a frightful disease," adding, "An icy period, an icy floating between our time and the Tertiary world!! Never!"

† "Pro. Geol. Soc. London," vol. iii., part ii., pp. 327-48.

‡ "Pro. Geol. Soc.," last cited.

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ice, and subsequently glaciers, existed in these portions of the United Kingdom, at a period immediately preceding the present condition of the globe, founding his belief upon the characters of the superficial gravels and erratic blocks, and on the polished and striated appearance of the rocks *in situ*." If, he says, the analogy of the facts he observed in the United Kingdom with those in Switzerland be correct, then he thinks "that not only glaciers once existed in the British Isles, but that large sheets (nappes) of ice covered all the surface." Young Mr Charles Lyell, afterwards the illustrious Sir Charles, followed with a paper on the geological evidence of the former existence of glaciers in Forfarshire, in which he stated that he had once attributed certain phenomena there to the action of drifting ice, but now accepted Agassiz's theory that glaciers had extended from the Grampians into the low country. This shows that Lyell had the courage to champion opinions which the majority derided or denied, when he believed these opinions to be true.

As the Brazilian said, Agassiz found traces of glaciers everywhere. He considered that Scotland had once been a peculiarly glacier-ridden country. "As from the Bernese Oberland," he writes, "and from the valleys of the Reuss and Limmath, gigantic glaciers came down and stretched across the plain of Switzerland to the Jura, scattering their erratic boulders over its summit and upon its slopes at the time of their greater extension, and as they withdrew into the higher Alpine valleys leaving them along their retreating track at the foot of the Jura and over the whole plain, so did the glaciers from Glen Prosen, and parallel valleys on the Grampian mountains, extend across the valley of Strathmore, dropping their boulders not only on the slopes and along the base of the Sidlaw Hills, but scattering them in their retreat throughout the valley, until they were themselves reduced to isolated glaciers in the higher valleys. At the same time, other glaciers came down from the heights of Scheihallion on the west, and descending through the valley of the Tay, joined the great masses of ice in the valley of Strathmore, thus combining with the eastern ice-field,—just as the glacier from Mont Blanc and the valley of the Rhone formerly combined in the western part of Switzerland with those of the Bernese Oberland. The relations are identical." He continues—"Among the localities of Scotland where the indications of glacial action are most marked, is the region about Stirling. Near Stirling Castle the polished surfaces of the rocks, with their distinct grooves and scratches, show us the path followed by the ice as it moved down in a north-easterly direction, toward the Firth of Forth, from the mountains on the north-west. To the west of Edinburgh, also, there is a broad glacier track, showing that here

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also the ice was ploughing its way eastward to find an outlet on the shore." * He considered that, in the district around Ben Cruachan, the glaciers moved westward and southward; about Aberdeen, eastward; and in the vicinity of Elgin, northward. The Grampians, Ben Wyvis, the Pentlands, Cheviots, and Westmoreland Hills were all centres of dispersion, from which glaciers radiated. Wales and Ireland bore similar evidences of glaciation. But Agassiz applies his theory not merely to Switzerland and Britain, but to a large portion of Europe. He tells us that "not only the Baltic Sea but the German Ocean also was bridged across by ice,† on which masses of Scandinavian boulders were transported," and are now found scattered upon English soil, and over the plains of Northern Germany. He holds that "a continuous sheet of ice once spread over nearly the whole continent" of Europe, while glaciers descended from every mountain range. "As the general ice-sheet broke up and contracted into local glaciers, every cluster or chain of hills became a centre of glacial dispersion." The glacial theory of Agassiz thus involves, *first*, a nearly universal ice-sheet, and *next*, local glaciers. This was his theory as applied to Europe. Let us turn now to his application of it to North America.

He gives us this as his sketch of "The Ice Period in America." He landed in America in the autumn of 1846, and had no sooner set foot in Halifax than "he was met by the familiar signs, the polished surfaces, the furrows and scratches, the *line engraving* of the glacier so well known in the Old World." After examining the North American continent in various directions, he became convinced that it also had once been nearly universally subject to glacier action, for he found that "the usual characteristic marks of glaciers extend over the whole surface of the land in the eastern half of the North American continent." Traces of ancient glaciers had not been, in his day, studied west of the Rocky

* Dr Buckland remarks that Agassiz attributed to glacial action the grooves and scratches observed on Corstorphine and Calton Hills, Edinburgh.

† It was in 1843, in a paper contained in the "Edinburgh New Philosophical Journal" (vol. xxxv. pp. 1-29), that Agassiz first suggested that the basin of the North Sea may have been filled with ice during the glacial epoch, his words being (foot-note, p. 19), "The North Sea of the glacial period had therefore either a much lower level than at present, or else, as seems to be almost proved by a consideration of the whole phenomena, its basin was filled to the bottom with solid ice." This is a much stronger expression than that the North Sea was "bridged across by ice," as stated subsequently by Agassiz in the "Geological Sketches" referred to in my Address. Since delivering this Address, I have learnt that Dr James Croll, F.R.S., an eminent Associate of our Society, arrived, in 1865, at a conclusion somewhat similar to that announced by Agassiz in 1843, without ever having heard of Agassiz's views. Dr Croll suggested the invasion of the North Sea by land ice during the glacial epoch, in a paper which appeared in *The Reader* of 14th October 1865.

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Mountains. He describes the whole surface of the immense uniform plain, east of the Rocky Mountains, as "glacier-worn, from the Arctic regions to about the 40th degree of northern latitude, the glacier marks trending from north to south" as a general rule. The higher points of the Alleghany range are not glacier-worn, but the depth of the great "continuous sheet" of ice which moved over the country may be gauged, by observing the height at which it scored and furrowed the Alleghany Mountains. "Mount Washington, for instance, is about 6000 feet high, and the rough unpolished surface of its summit, covered with loose fragments just below the level of which glacier marks come to an end, tells us that it lifted its head alone about the desolate waste of ice and snow. In this region then," he concludes, "the thickness of the sheet cannot have been much less than 6000 feet."

As I previously remarked, Agassiz, like Hutton, loved to trace the goodness and greatness of God in all His works. He asks why 'this great engine," the ice-sheet, was set at work ages ago to grind, furrow, and knead over the surface of the earth? "We have our answer," he replies, "in the fertile soil which spreads over the temperate regions of the globe. The glacier was God's great plough; and when the ice vanished from the face of the land, it left it prepared for the hand of the husbandman. The hard surface of the rocks was ground to powder, the elements of the soil were mingled in fair proportions, granite was carried into the lime regions, lime was mingled with the more arid and unproductive granite districts, and a soil was prepared fit for the agricultural uses of man." *

In another sketch he describes the glaciation of Maine. He says, regarding that State, that "the ice-fields, when they poured from the North over New England to the sea, had a thickness of at least five or six thousand feet." These ice-fields extended considerably into the Atlantic Ocean. "The aspect of the coast of New England," he concludes, "must then have been very similar to that of Greenland in its colder portions. Mount Desert itself must have been a miniature Spitzbergen, and colossal icebergs floated off from Somes's Sound into the Atlantic Ocean, as they do nowadays from Magdalena Bay."

Now, with all deference to modern glacialists, they have not advanced any more perfect glacial theory than this which Agassiz did many years ago. They have certainly supplied

* Referring to the glacial drift in Brazil, Agassiz remarks, "Wherever it lies thickest over the surface, there are the most flourishing coffee plantations" Paper on the "Valley of the Amazons." I may mention that Mr Melvin, formerly a Vice-President of our Society, informs me that some of the most fertile land in New Zealand is found on what he considers to be glacial drift.

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innumerable details in support of his theory, but in its bolder and wider conception, the credit of its origin and promulgation belongs wholly to Agassiz. A huge icesheet, 6000 feet thick, over-riding the land—a landscape like that of Greenland—oceans bridged, and mountains traversed by the moving ice—all these marvels were revealed by Agassiz to the astonished gaze of mankind. Yet he pushed his theory even further still. Men might perhaps acquiesce in its application to the temperate regions of North America. What would they say if he dared to apply it to the equatorial regions of South America? This is the subject of his last paper in these *Geological Sketches*, namely, one on the "Physical History of the Valley of the Amazon." Fully convinced of the universal application of his theory, and that "if the geological winter existed at all it must have been cosmic," that is, affecting the globe in general, and not only a small portion of it, he cared not if the announcement that he had found traces of glaciers at the Equator should "awaken among his scientific colleagues an opposition even more violent than that by which the first announcement of his views on this subject was met."

These "Geological Sketches" have rather a sad interest in the eyes of geologists, for they were Agassiz's fragmentary aud interrupted contributions to the science to which his voice had given new strength and a new revelation. We would willingly have seen the great promulgator of universal ice scouring hill and dale for the whole of his life in order to establish his theory in every quarter of the globe. Possibly Agassiz, too, would have gladly undertaken an universal ramble after universal ice; for he probably recognised the fact that, to the end of time, the name of Agassiz would be associated with that of his glacial theory, and that he would and could do nothing greater in the course of his life. But such was not to be. The eagle was to be chained to the Professor's chair or to the Museum's walls. Agassiz was too poor to be able to travel throughout the world, as Murchison and Lyell did, to obtain evidence regarding their theories, and there seemed to be no "Travelling Professorships" open in America to suit his case. Having lectured before the Lowell Institute at Boston, in 1846, and taken the city by storm, "he was at once called upon to lecture in the great cities of the country, and overwhelmed with invitations to meet with scientific societies and social assemblies." "Fascinating as a lecturer," says Dr Stebbins, "though pronouncing our language quite imperfectly, magnetic in his influence upon hearers," those who left the presence of Agassiz "knew not which had most captivated them, the perfectness of his knowledge, the transparency of his descriptions, or the warmth of his heart." Next

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year (1847) he was appointed Professor of Geology and Zoology in the Lawrence Scientific School, which was founded that year at Cambridge, in connection with Harvard University. And thus his life passed, with the single splendid excursion to Brazil, to the infinite benefit of American colleges, if not of the science of geology.

After teaching for fifty years, and after shining like a sun in the brilliant cosmopolitan circle of science, from his early student-days to his latest public appearance, Agassiz died on 14th December 1873, at the age of sixty-six, worn out with his self-imposed task to give America one of the finest museums of Natural History in the world. The Americans recognised the loftiness and purity of his aims. At the meeting of the Board of Regents of the Smithsonian Institution, held on 19th December 1873, his funeral oration was pronounced by one who perished, like Agassiz, in the service of the United States of America, whose aims were as lofty and pure, and whose cruel death, when President of the Republic, sent as great a thrill through the entire civilised world. At that meeting General Garfield spoke of Agassiz as follows:—"Few lives were ever so sincerely and entirely devoted to the highest and best aims of science. I was led to appreciate this by a remark which Professor Agassiz made to me several years ago, which is, I believe, the key to his own career, and deserves to be remembered by all who would follow in his footsteps. His remark was that he had 'made it the rule of his life to abandon any intellectual pursuit the moment it became commercially valuable.' . . . . While he was the prince of scholars, and a recognised teacher of mankind, yet he always preserved that child-like spirit which made him the most amiable of men. . . . . His death will be deplored in whatever quarter of the globe his genius is admired and science is cherished. He has left behind him, as a legacy to mankind, a name and a fame which will abide as an everlasting possession."

II.—*On Sections exposed in cutting the Suburban Railway at the Canal near Megget land, by* JOHN HENDERSON.

(Read 21st December, 1882.)

Mr HENDERSON is engaged working these sections more fully out, as well as several recently exposed. The whole subject will be fully considered in a paper to be read before the Society next session.

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III.—*Notes on the Submergence of Scotland, by* DAVID CAMERON, Daviot.

(Read 21st December, 1882.)

CONTENTS.—1. Land Ice and Floating Ice. 2. The Sand Hills and Terraces of Strathnairn. 3. Blocks resting upon the same. 4. Blocks on the hills of Strathnairn. 5. Sand and Gravel Formations in Athole and Argyleshire. 6. Blocks on the hills of Athole, &c. 7. Kames.

1. THE old red blocks of Morayshire and its vicinity do not occur in the interior of the country, but the blocks belonging to the interior are strewed all over the plains of Moray, and the ridges of the Black Isle. Most of the blocks perched upon the S.W. and S. sides of the Strathnairn hills are not native, but evidently belong to the basin of the Ness. The S.W. slope and summit of Doune Daviot are strongly glaciated. Its talus spreads out to N.E. Two round hummocks (700 feet), of fine sand are situated upon this talus, and they are strewed with large blocks of conglomerate and Doune Daviot gneiss, all streaming eastwards or across the line pursued by the land ice. Along the N. ridge of Strathnairn we see how the old red sandstone beds were torn up by continental ice. The old red blocks are strewed along the line of junction of the old red and the gneiss, and rest chiefly on the gneiss. Many of these blocks have been moved only a few inches in their native beds. But among them may be found blocks which are not native. These are also strewed over the sandy ridges in long streams to the E. or nearly so. No blocks could be deposited upon continental ice, but they would fall down when the valleys were well filled with glaciers, upon which they would be carried along. It is thus evident that the blocks of the Ness basin, which are found profusely in Strathnairn, must have been transported thither on floating ice. It would require a submergence of at least 800 feet to bring them from their habitats through the straights of upper Strathnairn and Loch Ruthven, and 1300 feet to bring them over the ridge.

2. The sand formation extends from Faillie to Nairnside, or 3½ miles in length, and from 200 yards gradually to 800 yards in breadth. Fine gravel and sand occur in patches along the N. ridge of Strathnairn down to the sea, where it assumes the form of great terraces nearly 100 feet high. At Daviot it traverses the ridge in a hollow (728 feet), and also occurs as a large compact body on the highest part (800 feet), about 1½ mile N.W. of Faillie. The sand also extends along the S. side of the valley

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from Scatraig seawards. It does not occur along the bottom of the valley. As seen from the bottom of the valley, it generally assumes the form of rough terraces, particularly on the N. side. The stratification is generally very fine, and often horizontal or nearly so, as seen in numerous sections, with a depth of from 50 feet to 100 feet. The whole formation appears to rest upon thick beds of clay. The terraced slopes have an angle of about 30°. The sand rises on both sides of the valley to a level of 700 feet above the sea, or 200 feet above the river. The distance across the valley between these sand levels (700 feet) varies from 1 mile to ¾ of a mile. A large plateau (635 feet) of this formation occurs at Farr. At Dunlichity there occurs a fine amphitheatre formed in a kame, known as "the Old Preaching Hollow." Its upper diameter is about 120 feet, and the level space in the bottom is about 12 feet diameter. Its acoustic properties are wonderful. The sand, particularly in the hollows, is covered with very fertile diluvium many feet in depth. Its surface is distinguished by its luxuriant grass and fine crops yielded under cultivation.

Very fine terraces of stratified sand and gravel occur along the south side of the lower reaches of the Nairn; above Drumore of Clava and Finglack (800 feet); from behind Daltullich to Finglack (600 feet); from Daltullich to Cantraydown (500 feet); from opposite Cantraybruich to West Galcantray (400 feet). The height of the opposite ridge at Culloden is about 500 feet. Thus we have to seek the corresponding or opposite terraces to the above (600-800 feet) on the other side of the Moray Firth, or along the N. side of the Ness valley.

In many places these and similar terraces are chiefly formed of clay. The occurrence of Arctic marine shells *in situ* at considerable elevations is one of the most striking proofs of a general submergence. The terraces are intersected by rocky promontories. They retreat, delta fashion, up the lateral glens. Each promontory, estuary, and bay can be traced with precision. Wide gaps occur where their cause is not so apparent, but the directions taken by the streams of blocks suggest lateral marine currents. This may be observed in the terraces below Doune Daviot.

3. The Daviot sand hills, as shewn by the numerous sections, contain no large blocks, but great blocks of gneiss, granite, schist, and conglomerate are strewed over their surface. These are generally embedded a few feet in the loam and sand. Some of the conglomerates resemble the rocks *in situ* on Faillie Moor; others the conglomerate at Duntelchaig. The granite and schistose blocks closely resemble the rocks of Stratherrick. Many blocks of the Doune Daviot gneiss, from 3 feet to 8 feet

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diameter, were rafted east for several hundred yards, and deposited upon the sand hills. A conglomerate monolith, standing 10 feet high, 12 feet broad, and 4 feet thick, occurs on a hummock (600 feet), N.E. of Daviot House. Two other conglomerates like it, and about the same size, are deposited in a sandy hollow (728 feet), on the ridge near Balvonie. A much larger one occurs on the sand formation (800 feet) 1½ mile N.W. of Faillie. Granite blocks are strewed around it on the sand and gravel ridges. Similar blocks form the stone circle at Daviot Mains. The largest one, situated on the S.W. side of the circle, is a cone-shaped conglomerate, 9 feet high, and 4 feet mean diameter. None of these blocks seem to belong to Strathnairn, but resemble the rocks of Stratherrick and its vicinity.

On the sandy plateau (635 feet) at Farr, there occurs a remarkable group of schistose blocks, many of them as large as a cottage. They resemble the rocks of the watershed to the S.W. A similar cluster occurs on the hill side (750 feet) above Craggie. Large blocks of granite, gneiss and conglomerate, are deposited upon the highest gravel terraces and gneiss rocks from Clava to Dun Even. The Old Red Rocks here are well covered with sand. The line of junction goes from the back of Meall Mor of Daltullich (1000 feet) to Clava (468 feet), due N., from thence to Cantraydown, N.E., from thence to Easter Galcantry, N.E., and from thence E. On the terrace (500 feet) above Clava there are three gneiss blocks, 8, 9, and 16 feet diameter; five conglomerates, 8, 9, 10, 15, and 17 feet diameter. On the opposite ridge (500 feet) at Culloden occurs the large flat conglomerate, known as "Cumberland's Stone," upon which the Duke of Cumberland stood on the morning of the battle to survey the field. The largest conglomerate in the district occurs near the terrace (400 feet) opposite Cantraybruich.

In the vicinity of Loch Ruthven (700-900 feet) the unreclaimed soil consists of sandy clay, covered with a "web" or layer of large boulders of granite and gneiss. In reclaiming the soil it invariably appears that this "web" of boulders is merely upon the surface, and seldom embedded deeper than 2 feet. After clearing them off, the ground is allowed to lie fallow all winter, so that it may get loose, by exposure to the atmosphere. Next spring it can be easily drained and ploughed. The conglomerate precipice, "Craig Dhearg," is largely composed of these granite and gneiss blocks, often 3 feet diameter, and arranged with their longest from S.W. to N.E. A fine rock section occurs here.

4. The hill south of Loch Clachan is profusely strewed with huge gneiss blocks, often finely perched upon the gneiss *in situ*. The hill on the N. side of this loch is strewed with

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gneiss blocks and also conglomerates. The line of junction from Craig Dhearg passes N.E. along the W. side of the hill.

On Ben Beurlaich (1575 feet), resting upon the granite, we observe on the S. side (1500 feet), two gneiss blocks, 3 and 6 feet diameter; a little higher, another 8 feet diameter. On the S.W. side (1550 feet), three gneiss blocks, 4, 5, and 6 feet diameter. A little lower, one block Stratherrick granite 5 feet diameter; and one gneiss block 5 feet diameter. On the summit, four gneiss blocks 2¼, 3, 4, and 5 feet diameter. On Ben na Caillach (1800 feet), on the gneiss *in situ*, four schistose blocks, 8, 9, 11, and 12 feet diameter; three granites, two at 2½ feet, and one at 5 feet diameter, On the ridge (1750 feet) to the E., three granites, two at 3 feet, and one at 5 feet diameter. On the S.W. side (1700 feet), three gneiss blocks about 6 feet diameter, and one granite 4 feet diameter. On Carnnan Uisgean (2017 feet), on the S.W. side (1800 feet), one conglomerate 7 feet diameter—the highest conglomerate known in the district—one gneiss block 9 feet diameter; at 1900 feet, three granites, 4, 5, and 8 feet diameter. On the W. part of the summit (2017 feet), on red porphyritic rocks, one granite block 4 feet diameter, and a profusion of smaller granites. On the E. part of the summit, on the gneiss *in situ*, four granites, 3, 4, 4½, and 8 feet diameter. On the summit (1550 feet), to W. by S., one gneiss block, split in two halves, 5½ feet high and 8 feet across the split. Granite blocks occur here also; and all over Carna Choire Mhoir (2054 feet) to the N. of the pass of Slochd Muick.

5. Meall Uaine, in Athole, is flanked with a terrace 1400 feet above sea-level, or 1000 feet above the Garry. Its sections reveal a great number of large blocks, and they are strewed upon the terrace. It runs to W. by N. The blocks are streaming in this direction. The 1000 feet contour in Athole very often presents a terraced appearance—in Glentilt, Glengirnaig, the Vale of Athole, and on the N. side of Strathtay.

The whole of the hill face and summit (1000 feet), at Lude and Strathgroy is a vast accumulation of find sand, well covered with fertile loam, particularly in the hollows. The great plateaux (1000-1300 feet), on the east side of Glentilt, and between Loch Moraig and Glengirnaig, are also of a similar formation. Very few blocks occur either in the sections or upon the surface. Great mounds of sand and gravel occur at lower levels, such as at Essengael, Clunebeg, and Aldclune. In some places the mounds, as seen from the bottom of the valley, assume a broken, terraced appearance, like those of Strathnairn. Similar formations are abundant along the banks of the Tummel. Many of them resemble Tomnahurich and Torvean in the Ness valley.

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Abundant traces of the sea are to be seen around the flanks of Ben Cruachan, along the slopes of Loch Awe, down by Glenaray, and round by the head of Loch Fyne. The hills above the Point of Morven, facing Loch Sunart, have a terraced appearance almost to their summits (about 1000 feet). These terraces of Morven may be seen to the best advantage from the promontory of Ardslignish in Ardnamurchan. Another terrace at Ardslignish is nearly 200 feet high. It winds along the loch side. Behind it rises a still higher and grander terrace showing the outlines of the ancient bays and promontories in lines parallel with the lower terrace. The diluvium may be observed higher up on Ben Hiant. The last retreat of the sea from the inland parts is well marked by the terraces of the valley of the Tay (290 feet): those of the Great Glen, of the Sound of Mull, and Loch Sunart.

6. On the hill (1200 feet), south of Aberfeldy, may be observed several boulders of grey granite, 3 feet diameter, on the ridge sloping to W. The glacial movement was from N.W., as indicated by the *roche moutonneés*, on both sides of Strathtay. All the blocks on the higher ridges, such as Ferragan (2579 feet) and Craig Forinal (1675 feet), are chloritic schist like the rocks *in situ*. The granite of the Grampians to the N.W. and that vicinity is red, that is, from the W. side of Glentilt along by Ben Dearg (3550 feet), Carn Dearg (1600 feet), Glenbruar, the higher reaches of the Garry and the braes of Rannoch. Grey granite occurs *in situ* near Loch Errocht. Boulders of the same are strewed over the braes of Rannoch. The grey granites in Strathtay evidently came from this direction. To the E. of Glentilt, along by Ben'y Gloe and the head of Glengirnaig, grey granite occurs *in situ*. Boulders of grey granite occur along the lower reaches of the Tilt up to levels of several hundred feet above the river. The terraces of Glentilt and Glengirnaig (1000 feet) run to S.W. The grey granites were evidently carried in this direction from their habitats.

Southwards, on the old red ridges of the Stormont, may be observed the schistose blocks of Athole, streaming from N.W. to S.E., following the track of the glaciation as indicated by the *roche moutonnées* here. The great northern valleys were also successively swept by glacial and marine currents to N.E.

7. In Strathnairn, below Mid Lairgs, there are several parallel ridges (700 feet) or kames along the south side of the valley for nearly a mile. The sections show large rounded gravel, and, in some parts, sand arranged in layers. Some parts of the kames are broad and gently sloped; other parts are very narrow and steep, like the ridge of a house. It is admitted that these and similar ridges are too steep to have been formed under water, and it is

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assumed by some geologists that they are of subglacial origin. It is quite obvious, however, that they had no such origin. The gravel is rolling down their sides, and the floods which occasionally sweep along by their base carry away or spread out the fallen material. The same process operated formerly where the sides are now more or less covered with heather. The subglacial theory is also disproved by the greater breadth and gentler slope of other parts of these kames where no torrents encroach upon them, and by the broad drums and billowy hummocks of similar formation running parallel to these narrow ridges, from which they are only divided by the water courses cut through the formation. Kames often wind across valleys, and always with the convex side seawards. A very large kame (800 feet) crosses the Nairn valley between Farr House and Brin Rock. The gap through which the Nairn (600 feet) flows may be seen to the best advantage looking south from Achvanaran. The Findhorn is also hemmed in by similar formations at Tomatin, Altnafree, and Pollochaig; the Garry in Glengarry and at Killiecrankie. A kame forms the watershed between the valley of Moy and that of Craggie. The burn of Craggie bisects the kame. The sections are the largest in the district. The stratification is very fine and almost horizontal.

When the sea retired the kames dammed up many of the valleys, and transformed them into lakes. The broken barrier and its old lake basin plainly reveal their own history. The basins on the Findhorn and the Garry show two successive parallel terraces; the higher terraces evidently mark the maximum height of these lakes. The kames are in every instance at least as high as the highest terraces. The substantial character of the kames and the bold outlines of the terraces afford a striking proof of the long continuance of these lakes.

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IV.—*Additional Notes on the Geology of the Enzie.* By THOMAS D. WALLACE, F.S.A. Scot., F.E.I.S., Headmaster of the Inverness High School.

(Read 18th January 1883.)

NOTE No. 1.

The following Notes are supplementary to the paper on "The Geology of Rathven and Enzie," which is to be found in the Society's "Transactions," Vol. III., part iii., p. 331.

Travelled Boulder.—On the 14th of July 1881, while on a visit to the Enzie, I had the pleasure of seeing and examining a very remarkable carried boulder. It was found on the farm of Gollachy, about 600 yards from the farm house, in a mossy field which was being drained. It was taken to the steading and thrown aside unnoticed, for there was nothing remarkable about its appearance to attract attention. It was an ordinary water-worn block of light red granite. Building operations commenced some time after its discovery, and the granite boulder was destined for a corner stone, for which purpose it had to be broken up. When split by the mason it was found to contain a rounded kernel of similar granite. It is fifteen inches long, fourteen inches high at the one end and eleven at the other. The thickness of the shell varies from $1\frac{3}{4}$ to $4\frac{1}{2}$ inches. The longest and shortest diameters of the inner mass are $10\frac{1}{2}$ and $6\frac{1}{2}$ inches.

Composition.—It is composed of black mica, with ferruginous quartz, and a very small proportion of felspar, if any at all. The inner mass is perfectly smooth, and if found on the sea-shore might attract no more attention than any ordinary water-worn stone. The rock, *in situ*, has not been identified. The preservation of this interesting specimen is due to the present farmer, Mr George Thomson, a gentleman who is both a keen geologist and an ardent lover of archæology. His taste for these sciences has preserved many fine specimens, which if fallen into the hands of others of his class would have certainly been lost to science.

NOTE, No. 2.

Porphyritic Diabase.—On another visit to this interesting district, in July 1882, I examined the conglomerates in the neighbourhood of Fochabers. There are two streams flowing into Fochabers Burn, which are called the "Dramlachs." In

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the one nearest Fochabers there are magnificent sections of Old Red Conglomerates, about 70 feet high, and so narrow is the path cut by this tiny stream, that when standing in the middle of it, both sides can be easily touched by the arms extended.

On examining the composition of this rock I found very characteristic specimens of the Porphyritic Diabase, which is found in Gollachy Burn, about five miles, in a N.N.E. direction, from this place. As the glaciation of the Enzie can easily be proved to have been from the W. or N.W., this seems to point to another locality of volcanic action in Old Red times somewhere to the W. or N.W. of the "Dramlachs."

Graphic Granite.—In the "Little Dramlach," which is the other stream referred to, the sections are not on so grand a scale. I entered this stream with the intention of walking across the country to the Enzie, and in doing so I was more than repaid for my toil. Not long after entering this stream, it was my pleasure to pick up from among the gravel a good specimen of Graphic Granite.

Kyanite.—In an out-crop of schist, a little further up, I was able to identify Kyanite *in situ.* By the aid of a piece of wood extemporised for a chisel, and a stone for a hammer, quite enough was procured to prove the discovery of this new locality. Numerous specimens of Kyanite had been picked up on the fields a few miles to the east of this, but no one could ever say whence they came.

Old Red Clays and Sand.—After crossing the moor I entered "Braes Burn," which has cut a bed out of Old Red Clay and Sand. There are some remarkable specimens of denudation here; but I will only refer to two of them. One is an isolated mass of sand which still retains a cap of turf, and supports a small tree. The other is a section of the same sand, exposed by a stream, formed by the surface drainage in wet weather, for in summer it is dry as it was on my visit. This dry bed is about 200 yards long, 20 feet deep, and from 10 to 15 or 20 feet wide.

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V.—*Structural Geology of the Northern Extremity of Glen-more-nan-Alban, by* THOMAS D. WALLACE, F.S.A. Scot., &c.

(Read 18th January 1883.)

FIRST PART.

GLEN-MORE-NAN-ALBAN needs no one to sound the praises of its great natural beauty, which attracted and received the admiration of the earliest Scottish tourists, and is still annually visited by hundreds, who pass through it filled with continued appreciation of its matchless scenery. There are at least two classes of visitors to this and other favourite resorts: those who pass through with a high sense of the beautiful, and thus derive decided benefit from the visit; others whose sole intention is to "do the place." The latter may be said to derive no benefit, but only a kind of time-killing, undefinable satisfaction that they have been somewhere and seen something that every one is expected to see. But the "Great Glen" possesses an interest, whose presence the most ardent admirer of picturesque scenery or the mere sight-seer never cares to know. We by no means desire to despise the lover of nature, neither do we mean to neglect the great natural beauty of those parts of the Glen to which we are about to refer: but our chief object is to call attention to one or two points in its geological structure, and in doing so we will confine our remarks to a very small portion of this valley, namely, that which extends from Inverness to Glenurquhart, a distance of 14 miles, about 5 of which are occupied by the River Ness, and the remaining 9 miles by Lochs Dochfour and Ness. This part of the loch is about 2¼ miles wide, and opposite Templehouse, Glenurquhart, is 128 fathoms deep.

From the summit of the hills on the west side of the loch a very good general impression of the district now under review may be obtained. The hills descend very abruptly to the water's edge on the west side, and with a very gentle slope on the east, except in the neighbourhood of Inverfaracaig and Foyers. Standing on one of the points already referred to, and looking to the north-east, the country has the appearance of an immense plain as far as the eye can reach. From the hills which extend from Abriachan and Craigphadrick the land rises very gradually towards the south, till it reaches the Nairn hills. The great contrast between the contour of the granitic and gneissose rocks on the west of the glen, and that of the Old Red on the east is well observed from this point.

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The Caledonian Valley has long been said to represent a great fault or down-throw, which is continued throughout the entire length of the Moray Firth. By this fault or down-throw the upper beds of the Old Red on the east side of the glen and south side of the Moray Firth are thrown down against the lowest beds of the same system on the west side of the glen and the north of the Moray Firth. At Inverness the upper beds of the Old Red on the east side are thrown down against the lowest or conglomerate beds of the same system on the west.

Again, opposite Abriachan, the upper beds on the east are thrown down against the granite and gneiss of the west. These two sections clearly point to a fault, but the presence of conglomerate on both sides of the loch at Inverfaracaig would appear to contradict the theory, and suggest the question of the extent of the dislocation. Does it extend throughout the entire length of the glen uninterruptedly, or have we a cross fracture in the neighbourhood of Foyers still to discover? The conglomerates to the west of Dunriachy show several decided slips; but whether there is any dislocation between that and Foyers, or in the neighbourhood of Foyers, I have not been able to determine.

Some fault or slip, or down-throw, was no doubt the original cause of part of the valley; but it has subsequently been subjected to great erosion, proofs of which may be seen on both sides of the glen. The fact that the loch is deepest towards the middle also points to denudation by ice. As far as Loch Ness is concerned, the direction of the latest glacier has been towards the Moray Firth in the line of the glen. This can be clearly proved from several carried blocks of granite and hornblende, which are found *in situ* in Abriachan. The streams which descend from the hills into the loch cut through portions of well marked terraces, and expose in several places good sections of boulder clay containing numerous specimens of well-known rocks to be found *in situ* to the west of their present position.

The valley of the Ness, from the loch to the Moray Firth, consists of deposits of clay, sand, and gravel, which sometimes take the form of terraces on the sides, and ridges across the valley. The ridge of which Tomnahurich must at one time have formed a part lies across the valley and joins with Dunain. On this ridge is situated the supposed site (by some) of King Bruid's Castle. The contents of these ridges point clearly to the rearrangement, under water, of previously existing morain matter. The terraces have been described by Chambers and others, and I will only remark here, that as many as four distinct ones can be traced near Dunain, and are seen to great advantage from the opposite side of the river.

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The hills on the west side are in some respects more interesting than those on the east, and the following order may be observed by any one travelling along the road from Drumnadrochet to Inverness: (1.) Old Red Sandstone Conglomerate, (2.) Gneiss, (3.) Granite, (4.) Gneiss, and (5.) Old Red Sandstone Conglomerate.

Glenurquhart.—This district which has been the favourite resort of pleasure-seekers and artists, for many years, has long been celebrated for its minerals, as well as for its beautiful scenery and mild climate. The Inverness Scientific Society and Field Club visited Glenurquhart under the leadership of Professor Heddle of St Andrews. This eminent mineralogist pointed out to the members present the following minerals, which they had the pleasure and satisfaction of gathering from the rocks *in situ*—Serpentine, Hydrous Anthophyllite, Wollastonite, Biotite, Chondrodite, Kyanite, Edonite (Brown and Green), Tremolite, Actinolite, Andisine Felspar, Apatite, Sphene, Zoisite. When all these can be gathered in a few hours, in one small district, no further proof can be wanting of its rich mineralogical character.

Abriachan.—This is a small district on the west side of the loch, about six miles from Inverness. It has been made more accessible by the formation of a pier to enable steamers to call with and for passengers. Close by the side of this pier is a very ancient burying-ground, containing a fine old sculptured stone. The Abriachan Burn has cut through a section of Granitic Gneiss, and formed one very beautiful waterfall, which in spring and autumn is embosomed in a variety of charming foliage. From this the stream falls by a succession of leaps into the loch. This beautiful birchen and hazel glade is overlooked by two high and bald rocky summits, and one of these will have our attention for a few minutes. The hill to the north of the burn is composed of a small-grained light-red granite, which is at times quarried for building purposes. This appears to be a metamorphic granite, changed by chemical action out of the Silurian rocks themselves. Specimens of this granite can easily be obtained, containing fragments of the Silurian rock unchanged, as if the granite had cooled before the process of metamorphism had been completed. Veins of the same granite can be seen penetrating the adjacent rocks, which in mass present a very broken appearance. They are broken by vertical and horizontal lines into innumerable small angular fragments. The granite in the quarry is similarly broken, but into larger blocks, the sides of which show good examples of "slicken-sides."

This quarry has been rendered famous by having its name given to a mineral found here, which was pronounced by Pro-

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fessor Heddle to be new, and called by him "Abriachanite." This mineral, which is of a bluish-white colour, is very plentiful in the district around Inverness. Specular iron ore and Epidote are also plentiful in Abriachan granite. Veins of the former have been got half an inch thick. In August or September of 1882, I found associated with Abriachanite, Epidote, and Specular iron, another mineral, which has been identified by Mr Macadam as Fluor-spar.

About 300 yards west of the ninth mile-stone from Inverness to Glenurquhart, an interesting section of hornblend, gneiss, and granite is exposed on the roadside. The length of the whole section is 48 yards. Measuring from west to east we first get 13 feet of hornblend, then 72 feet of gneiss, next 37 feet of hornblend, and then 13 feet of gneiss, of a wedge shape; next comes 15 feet of granite, and lastly 13 feet of hornblend. Gneiss comes next, and continues till it joins the granite of Abriachan.

The hornblend is in rounded masses, but *in situ*, and is overlaid by gneiss, between which there is a deposit of boulder clay, which is exposed for 6 feet, and contains water-worn pebbles of granite and gneiss. This clay varies in thickness from 2 to 3 and 4 inches, and may possibly be found to extend to 17 feet in length, but this extension is doubtful. At the other end of the section a similar bed of clay with pebbles extends for 2 feet 7 inches, with a thickness of 3½ inches. One of the interbedded pebbles measured 4½ by 1½ inches.

Another interesting section of gneiss and hornblend is seen at the eighth milestone. The length of the section is 35 feet. Between the overlying gneiss and the hornblend there is a decayed band of hornblend. The rock that joins this section on the west is a granitic gneiss broken as described above.

Caves.—There are two small caves not far from this section, out of which the writer has obtained several beautiful stalactites, one of which measures about two feet long, and weighs a stone.

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VI.—*Additional Note on the Old Red Sandstone of Strathnairn.* By THOMAS D. WALLACE, F.S.A. Scot., &c.

(Read 18th January 1883.)

THE following note may be considered as an appendix to the paper to be found in the Society's Transactions, vol iii., part ii., p. 213.

By reference to the map accompanying that paper the district to which I am about to refer may easily be found. It is a small piece of moorland lying to the west of Loch Ashie, and extending in the same direction for fully a mile. This little district, which is about a mile square, is remarkably rich in archæological remains. It was with the view of revisiting these illustrative relics of the primitive inhabitants of our country that I accompanied Mr Fraser, a well-known member of the Society, to the district in November of this year (1882). We found numerous out-crops of Old Red Sandstone, one of which differed in some respects from any that we had formerly observed in Strathnairn. It is a foliated sandstone, the foldings in some instances being peculiarly interesting. This was probably the source from which the cairn builders procured some of their materials, for the "Grey Cairn," which is situated about four miles to the east of this, contains many specimens of this rock. Another section shows some remarkable false bedding. The layers of the rock are very thin, so thin that they might well be used for roofing slate. I have been told that they have been quarried and used for this purpose. One granite pebble was picked out of this thin bedded rock. Here also may be seen the finest specimens of sun-cracks. Those at Burghead are often referred to, but those here are equally fine and certainly more numerous. All the rocks dip in the usual direction of the rest of the Old Red system here, viz., 14° N.W.

About three quarters of a mile west of Loch Ashie, and immediately under this cliff of Old Red lies the beautiful little loch called "Loch-nan-eun-ruodh" (the loch of the red bird, or grouse loch). On the shores of this loch is an out-crop of the shale which has proved so highly fossiliferous at Nairnside. On examining this out-crop on the above date, I found traces of fish, which extends the fossiliferous shale of Strathnairn several miles further west. My time was limited; but on a diligent search being made, I have no doubt from the appearance of the bed that good fossils might be found.

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VII.—*Note on River Erosion in Switzerland.* By R. T. Omond.

(Read 18th January 1883.)

Abstract.—In this paper Mr Omond pointed out that the River Aare, a short distance above Meiringen, had cut a deep channel in a rocky barrier of limestone; that this channel, which is 200 or 300 feet deep, is of post-glacial origin; and that the river has formed this gorge in preference to clearing out an old channel now filled with glacial débris.

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VIII.—*On the Results of the Analyses of Diatomaceous Deposits from the Peat of Kinnord, Ordie, Drum, and Black Moss, Aberdeenshire.* By W. IVISON MACADAM, F.C.S., F.I.C., Lecturer on Chemistry, and Analytical Chemist, Edinburgh, *Honorary Secretary to the Society.*

(Read 18th January 1883.)

AT the April meeting of the last Session of this Society, I read a paper "on the Analysis of a Sample of a White Deposit from the Peat of Aberdeenshire," in which the results were given of an examination of a sample received from Mr Wm. Hamilton Bell. Having placed myself in communication with the Rev. Geo. Davidson, minister of Logie Coldstone, I was enabled, before going to press, to add to my own results a very complete list of the Diatoms which that gentleman had identified in the deposit.

On receiving a copy of my paper Mr Davidson expressed the opinion that the comparatively large proportion of iron present in the sample might be exceptional, and I then asked him to send me further samples for examination.

The Rev. J. G. Michie of Dinnet also kindly forwarded portions of the deposit as found in his neighbourhood, so that I am now enabled to give the Society somewhat full results of the analyses of all the deposits now known in Aberdeenshire. In further apology for bringing this matter again before the Society, I may mention the interest shown by the outside public, as evidenced by the large number of applications I have received for copies of the paper, and which has emboldened me to lay these more full results before the Fellows of this Society.

The samples analysed are seven in number, and are derived from the deposits found in the Black Moss, Ordie Moss, Drum Moss, and Kinnord Moss. Three of the samples are from the Black Moss; No. 1 being from the margin of the deposit, whilst No. 2 is from the centre; No. 3 was obtained from Mr Michie. Nos. 4 and 5 are from Ordie Moss, the fourth from Mr Davidson, and the other from Mr Michie. No. 6 from Drum Moss, and No. 7 from Kinnord Moss; both from Mr Michie. These deposits do not differ much in appearance, being fallow gray in colour, tough to cut with the knife, and having numerous stems of *Phragmites communis*, *Equisetum limosum*, and *E. fluviatile*, with fragments of various species of

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Spagnum. It was considered that probably the deposits might vary according to the position more or less close to the side of the loch in which they were deposited, and the results somewhat bear out this theory.

The samples were analysed as handed to me, that being the condition in which the material finds its way into the market as a substitute for the Kieselguhr employed in the manufacture of dynamite. The results are given in Table A.

I have added to the results of these deposits the analysis of a sample of ordinary brown peat.

With the exception of the Drum Moss deposit, the amount of moisture averaged from 10·24 to 12·61 per cent. of the material, whilst the peat gave 14·16 per cent. Drum Moss deposit contains only 5·41 per cent., and is in accordance with the large proportion of siliceous matter this deposit contains.

The results were afterwards calculated to percentages free from moisture, so as to allow of their being readily compared one with another. The figures are given on Table B, and show very distinctly how greatly the deposits differ, even when portions are taken from the same bed.

In all cases the bright green solution of chlorophyl was obtained when the pulverized sample was treated with ether. The amount varies much, running from 2·272 per cent. in the Kinnord sample down to 0·275 per cent. in the Drum Moss, but in all cases the extractive matter was the same in composition.

The organic constituents, in other words the remains of the plant life which grew during the deposition of the Diatoms, also varies greatly in amount, being in the case of the Drum deposit as low as 4·503 per cent., and running up to 49·430 per cent. in the Ordie Moss sample.

Even in the same deposit much variation exists, for in the Black Moss deposit, near the centre, there is 34·533 per cent. organic matter, whilst at the margin of the deposit there is 41·949 per cent. This is doubtless due to the latter deposition having taken place in more shallow water with a consequently greater activity of vegetable growth.

The siliceous matter with its earthy impurities, or inorganic portion, also differs widely, being in the Drum Moss 95·221 per cent., and in one of the samples from Ordie Moss as low as 49·430 per cent.

Of the Black Moss samples that from the centre of the deposit has 63·387 per cent. of inorganic constituents, whilst that taken at the side of the deposit has 56·528 per cent., both results calculated on the dry substance.

The organic portion, insoluble in ether when subjected to

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analysis, gave results not differing greatly from those given in my previous paper, and in no case was the carbon less than 44·2 per cent., or more than 44·8 per cent. The hydrogen yielded similar results, the highest figure being 6·62 per cent., and the lowest 6·155 per cent. The oxygen varied from 48·612 per cent. to 49·569 per cent. of the organic portion. These results show that the source is similar in all cases, whilst the figures agree very closely with those calculated from the formula $C_6H_{10}O_5$, the chemical symbol for cellulose, the body forming ordinary wood structure. The percentage results of the organic portion are given on Table C.

The percentage results when calculated to the proportions as present in the original samples yield the figures on Table D. These results show distinctly the reason why the people of the locality do not cut the deposit for fuel, although the upper or overlying peat is regularly so employed. The very large proportion of ash, or inorganic constituents, would cause a large amount of waste, and would practically cause a double carriage of fuel from the moss, whilst the small proportion of organic combustible matter would make it worthless as a heating agent.

The inorganic portion on being analysed gave the results on Table E.

The true diatomaceous matter may thus be as low as 77 per cent., or, as in Drum Moss, 92 per cent. of the weight of the substance when free from moisture.

TABLE A.—WHITE DEPOSIT FROM PEAT.

Analyses of Samples as received.

	Black Moss.		Black Moss.	Ordie Moss.	Ordie Moss.	Drum Moss.	Kinnord Moss.	Brown Peat.
	Margin.	Centre.						
Moisture	12·61	10·52	9·92	10·42	10·32	5·41	10·24	14·76
Organic matter soluble in ether (chlorophyl)	1·33	1·86	1·89	1·02	2·25	0·26	2·04	3·05
Organic matter insoluble in ether (cellulose, &c.)	36·66	30·90	23·59	44·28	27·77	4·26	18·04	79·39
Inorganic constituents	49·40	56·72	64·60	44·28	59·66	90·07	69·68	2·80
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

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Table B.—White Deposit from Peat.

Results of Analyses calculated free from Moisture.

	Black Moss. (Davidson.) Margin.	Black Moss. (Davidson.) Centre.	Black Moss. (Michie.)	Ordie Moss. (Davidson.)	Ordie Moss. (Michie.)	Drum Moss. (Michie.)	Kinnord Moss. (Michie.)	Brown Peat.
Organic matter soluble in ether (chlorophyl) .	1·522	2·079	2·097	1·139	2.620	0·275	2·272	3·578
Organic matter insoluble in ether (cellulose, &c.)	41·949	34·533	26·188	49·430	30·965	4·503	20·098	93·137
Inorganic (constituents) .	56·528	63·387	71·714	49·430	66·414	95·221	77·629	3·284
	99·999	99·999	99·999	99·999	99·999	99·999	99·999	99·999

Table C.—White Deposit from Peat.

Ultimate Analyses of Organic portion.

	Black Moss. Margin.	Black Moss. Centre.	Black Moss.	Ordie Moss.	Ordie Moss.	Drum Moss.	Kinnord Moss.	Brown Peat.
Carbon . .	44·354	44·428	44·516	44·382	44·276	44·768	44·343	44·682
Hydrogen . .	6·195	6·454	6·321	6·392	6·155	6·620	6·218	6·227
Oxygen . .	49·451	49·118	49·163	49·226	49·569	48·612	49·439	49·091
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000

Table D.—White Deposit from Peat.

Detailed Analyses of Samples free from Moisture.

	Black Moss. Margin.	Black Moss. Centre.	Black Moss.	Ordie Moss.	Ordie Moss.	Drum Moss.	Kinnord Moss.	Brown Peat.
Organic constituents insoluble in ether—								
Carbon . .	18·606	15·343	11·661	21·938	13·710	2·015	8·912	41·615
Hydrogen . .	2·599	2·229	1·654	3·159	1·905	0·299	1·249	5·799
Oxygen . .	20·744	16·961	12·874	24·301	15·349	2·189	9·936	45·722
Organic constituents soluble in ether .	1·522	2·079	2·097	1·139	2·620	0·275	2·272	3·578
Inorganic constituents	56·528	63·387	71·714	49·430	66·414	95·221	77·629	3·284
	999·999	999·999	100·0	99·967	99·998	99·999	99·998	99·998

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TABLE E.—WHITE DEPOSIT FROM PEAT.

Analyses of Inorganic portion.

	Black Moss.			Ordie Moss.		Drum Moss.	Kinnord Moss.	Brown Peat.
	Margin.	Centre.	No. 3.	No. 1.	No. 2.			
I. *Soluble in water*—								
Calcic oxide	0·741	0·946	0·841	0·765	0·362	0·943	1·040	
Magnesic ,,	0·332	0·552	0·548	0·482	0·371	0·456	0·606	
Potassic ,,	0·076	0·213	0·224	0·187	0·108	0·315	0·327	
Sodic ,,	0·048							
Sulphuric anhydride	0·168	0·374	0·289	0·253	0·242	0·832	0·733	
Chlorine	trace	trace	trace	trace	trace	0·171	trace	
	1·365	2·085	1·902	1·687	1·083	2·717	1·716	5·362
II. *Soluble in hydric chloride*—								
Ferric oxide	1·903	1·343	2·885	6·565	2·273	1·459	4·120	
Aluminic ,,	0·236	0·429	0·407	0·201	0·154	1·104	1·854	
Calcic ,,	2·737	2·692	2·484	2·897	0·782	2·378	0·998	
Magnesic ,,	0·670	0·741	0·646	0·632	0·326	0·854	0·205	
Alkalies, &c.	0·268	0·187	0·215	0·194	0·103	0·358	0·143	
Phosphoric anhydride	...	...	...	..	...	...	...	
Soluble silica	0·541	0·621	0·437	0·441	0·281	1·121	0·921	
	6·355	6·013	7·074	10·930	3·919	7·274	8·241	17·068
III. *Silicates decomposed by hydric fluoride*—								
Ferric oxide	0.142	0·089	0·156	0·166	0·579	4·853	0·142	
Aluminic ,,	0·535	0·202	0·342	0·383	0·463	4·404	0·303	
Calcic ,,	0·114	0·132	0·127	0·155	0·432	2·136	0·058	
Magnesic ,, &c.	0·022	0·071	0·095	0·102	0·138	0·632	0·014	
	0·813	0·494	0·720	0·806	1·612	12·025	0·517	13·285
Silica principally diatoms	91·067	91·012	89·962	86·125	93·075	77·498	89·232	64.285
	99·600	99·604	99·658	99·548	99·689	99·514	99·706	100·000

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I am indebted to Mr James Thomson, F.G.S., Glasgow, for a sample of a diatomaceous deposit from the farm of Gress, in the Island of Lewis. Mr Thomson describes it as 20 inches thick, and forming the floor of a small basin, surrounded by extensive deposits of blown sand, and several feet above sea-level. The analysis yielded the following results:—

Organic matter	13·875
Inorganic matter	86·125
	100·000

ANALYSIS OF MINERAL PORTION.

Ferric oxide	8·841
Aluminic „	1·120
Calcic „	4·573
Magnesic „	1·322
Potassic „ / Sodic „	0·717
Sulphuric anhydride	0·786
Chlorine	0·611
Phosphoric anhydride	trace
Silica	80·638
	98·608

Ether, shows no Chlorophyl.

I am under a debt of gratitude to my friend Mr E. W. Burgess, the well-known microscopist, for the following extract and list of Diatoms found by him in this deposit.

DIATOMS FROM THE ISLAND OF LEWIS, N.B. (Roy. Mic. Soc. Jour., Oct. 1882, pp. 665-6.)

Mr E. W. Burgess sends the following list, made after an examination of a diatomaceous deposit, new to Great Britain, from the Island of Lewis, near Stornoway.

The list has been submitted to Dr Stolterfolk of Chester, for verification of most of the species. Abbreviations:—v. r. (very rare), signifies that only one or two valves have been found; r. (rare), about one on each slide; c. (common), three or four on a slide; v. c. (very common), the form most often met with on the slides.

Professor H. L. Smith's arrangement has been followed.

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Tribe I. Raphidieæ.

Family 1. *Cymbelleæ.*

Cymbella Helvetica, Ktz., c. C. maculata, Ktz., r. C. Scotica, W. Sm., c.

Family 2. *Naviculeæ* Mastogloia, sp., v. r.

Stauroneis anceps, Ehr., r. S. phœnicentrone, Ehr., v. r. S. punctata, Ktz., v. r. Navicula (including Pinnularia). N. angustata, W. Sm., c. N. acuta, W. Sm., c. N. firma, Ehr., v. r. N. Hebes, Ralp., c. N. interrupta, W. Sm., r. N. gibba, Ehr., r. N. major, Ehr., r. N. ovalis, W. Sm., v. r. N. Rhomboides, Ehr., v. c. N. viridis, W. Sm., c. N. viridula, W. Sm., v. r.

Family 3. *Gomphonemeæ.*

Gomphonema acuminatum, Ehr., c. G. capitatum, Ehr., v. r. G. constrictum, Ehr., v. r. G. intricatum, Ktz., r.

Family 5. *Cocconideæ.*

Cocconeis placentula, Ehr., v. r. C. Thwaitesii, W. Sm. = Achnanthidium flexellum, Breb., v. r.

Tribe II. Pseudo-Raphideæ.

Family 6. *Fragilarieæ.*

Epithemia gibba, Ktz., v. c. E. proboscidea, W. Sm., c. E. ocellata, Ktz., c. E. rupestris, W. Sm., c. E. sorex, Ktz., c. E. turgida, W. Sm., r. E. zebra, Ktz., r. Eunotia diadema, Ehr., v. r. E. tetraodon, Ehr., c. Himantidium Arcus, W. Sm., v. c. H. bidens, Ehr., v. c. H. undulatum, W. Sm., r. H. majus, W. Sm., v. c. Synedra splendens, var. Danica, O'Meara, Irish Dia., also several broken bent valves.

Family 7. *Tabellareæ.*

Tabellaria fenestrata, Ehr., c.

Family 8. *Surirelleæ.*

Tryblionella angustata, W. Sm., r. Surirella linearis, W. Sm., v. r. S. nobilis, W. Sm., c. Nitzschia linearis, W. Sm., v. r.

Family 10. *Melosireæ.*

Melosira nivalis, W. Sm. = Coscinodiscus Smithii, O'Meara, v. r.

Family 15. *Coscinodisceæ.*

Cyclotella antiqua, W. Sm., c.

Also a form not made out, rare.

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IX.—*Crude Suggestions on the Nomenclature of Rocks.* By G. H. KINAHAN, M.R.I.A., &c., &c., District Surveyor Geological Survey of Ireland, Associate.

(Read 15th February 1883.)

GEOLOGISTS are aware that at the present time the nomenclature of the rocks is in a most unsatisfactory condition; so much so, that geology has been in a great measure prevented thereby from taking its proper rank as a true science. This appears to be due to the want of some master mind like Linnæus, who did for Botany what it is desirable some one would now do for Lithology—that is, systematize the nomenclature, and lay down laws in accordance with which the names of rocks should be regulated and assigned. The person to do this should be a Geologist well acquainted with mineralogy and chemistry. I am well aware that I am not such an individual, but at the same time I may be excused for ventilating my ideas on account of the number of years of study and consideration I have given to the subject. I would, however, at the same time specially point out that the more I have considered the subject, the harder and greater the task appeared; therefore these crude suggestions are only put forward in the hope that they may induce those with the proper talents and time at their disposal, to devote both, to a proper working out of the subject.

In former writings I have suggested that some order might be produced if a system very like that in use in the science of Botany was adopted;* the whole of the rocks being divided up into ORDERS, the orders into GROUPS, the groups into SPECIES, the species into VARIETIES, and the latter into SUB-VARIETIES. As in Botany, so here also, to make such a system truly correct, it would be necessary to supersede the present popular names and introduce new ones, or such modifications of the old ones, that the name used would indicate whether the writer or speaker wrote or spoke of a group, species, variety, or sub-variety of rocks, and to which of them the rock belonged. The latter, however, I must allow appears to be a very difficult problem. To meet these requirements the group names and the specific names, at the least, ought respectively to be distinguished by names that have either a common prefix or termination.

In the "Handy Book of Rock Names" I suggested, after

* The names of the divisions to be given are somewhat different to those formerly put forward in the "Handy Book of Rock Names;" while, on the whole, as hereafter seen, the classification is materially different.

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Forbes, that the rocks should be divided into two orders, called *Ingenite* and *Derivate Rocks*, for the reasons there given. Such a classification, however, now appears to me to be open to serious objections, more especially as under it rocks closely allied, or made up of nearly similar materials, cannot be grouped together; such for instance, as grits, quartz rock, quartzyte, and vein quartz; rocks, all of which are essentially composed of silica, but formed under different conditions.

In considering the formation of a classification, various bases suggest themselves on which to originate a system, but after much thought and consideration all appear to me to be more or less open to objections, as none by itself gives a true natural classification, as the original bases will have to be more or less ignored before the system is complete. Nevertheless a chemical classification can be made to meet the requirements of the orders and groups; also nearly entirely to include the species,* but in reference to the varieties and sub-varieties, where structure has often to be taken into account, the classification cannot be solely chemical.

Such a system, for the most part chemical, but in part structural, should consist of three orders — *Order* I. to be called ACIDIC, *Order* II. BASO-ACIDIC, and *Order* III. BASIC; while, in compliance with what has been previously stated, the group names should have a common prefix or termination, which for the purpose of this paper may be the termination *lith*. As the paper is solely a suggestive one, it will be unnecessary to give all the groups into which the Orders should be divided; and as all the groups will not be given, consequently we cannot mention all the species, varieties, and sub-varieties. We will, however, give the principal groups of each Order, and subsequently suggestion as to how the specific names may be formed; followed with other suggestions in reference to the names of the varieties and sub-varieties; concluding with a few examples of rocks of Order I., showing how a table of them might be drawn out. We will begin by dividing the Orders into groups.

Order I. *Acidic* would include GROUP A *Silicolith*, or the eminently silicious rocks; GROUP B *Felsolith*, in which would be included the silicious granitic rocks (granytes and elvans), the silicious felstones, with all allied felso-silicious rock. These are the principal groups of this Order. As they would include the majority of the rocks, it is therefore unnecessary to mention the others.

Order II. *Baso-acidic*. This is an essential division, although it would be small, as most of the rocks would be included under

* It might possibly also be made to include the species if a radical change was made in rock names.

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GROUP A *Eurolith*, or the baso-felspathic rocks. Other groups, however, and some very important ones, would be found to belong to this Order when the classification was thoroughly worked out.

Order III. *Basic.* This would be more prolific in groups than either of the others, the more principal being GROUP A *Pyroxenolith*, or rocks having as their principal essential constituent pyroxene (augite); GROUP B *Amphibolith*, or rocks having as their principal essential amphibole (hornblende); GROUP C *Micolith*, or very micaceous rocks; GROUP D *Calcolith*, including all limestones; GROUP E *Magnesolith*, comprising the dolomytes, ophytes, steatytes, magnesytes, and other magnesian rocks. The other groups it is unnecessary to mention.

Before passing on to the species, I would again specially point out that such a common termination as *olith* (of course a common prefix would have a similar effect) would indicate at once that it was a group of rocks to which the speaker or writer referred.

So far a truly chemical classification presents few difficulties, but when we have to deal with the species, some are so eminently due to their structure that it is hard entirely to ignore it;* while, in addition, there is the name question, that is, whether the old names are to be retained or new ones substituted? Undoubtedly the more scientific course would be the latter—or a middle one—that is, adding to the old names a common prefix or termination. This seems to me a most important question, because if the old names are retained, any new classification will be perfectly incomplete; while if new names, or even prefixes or terminations to them are adopted, it will make such a radical change in rock nomenclature that many geologists will raise an outcry, more especially those who delight in using a name not in its original signification, but as it suits their fancy. Waving these questions, however, I may for the purpose of the paper suggest the Latin prefix of *de*, anglice *of* or *from* or *belonging to*.† The names of varieties ought also to be changed, the old names being kept solely for sub-varieties. This, however, I will not attempt, but will conclude these suggestions by giving tables of the rocks of Groups B and A in Order I., as illustrations of what the proposed classification would be like.

* A sandstone, for instance, may have an acidic or basic matrix, which often exceed in quantity the cemented particles of silica, or in some cases the particles in addition may not be silica, but some basic material, thus making the rock still more basic.

† It seems a pity that Celtic words are in general considered unscientific. Some indeed, such as Granyte (more correctly Granat) and Elvan (which some would Latinise into Elvanyte), are in use; but I am afraid if I proposed the Celtic prefixes of either *O* or *Mac*, anglice *belonging to*, there would be a perfect outcry, although either would be more expressive than the Latin *de*.

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In Group **A** the table will be complete to the varieties, while only some sub-varieties will be given, but in Group **B** an easier group to deal with the principal sub-varieties will appear.

TABLE OF THE ROCKS.

ORDER I.—ACIDIC.

GROUP **A** *Silicoliths.*

SPECIES A.—DEQUARTZ (Quartz-rock or Greissen).

Variety a, *Vein quartz.*
Sub-var. *a*, gaugue quartz; *b*, jasper rock, &c., &c.
„ b, *Chent.*
Sub-var. *a*, menilyte, &c., &c.
„ c, *Silicious sinter.*
Sub-var.
„ d, *Sandstone.*
Sub-var. *a*, silicious; *b*, calcareous; *c*, pyritous; *d*, ferriferous; *e*, conglomerate; *f*, breccia, &c., &c.

SPECIES B.—DEQUARTZYTE (Quartzyte or Quartz-schist).

Variety a, *Itacolumyte.*
Sub-var. *a*, Itabrit; *b*, fibrous quartzyte, &c., &c.
„ b, *Felso-quartzyte.*
Sub-var.
„ c *Mico-quartzyte.*
Sub-var.

GROUP **B** *Felsoliths.*

SPECIES A.—DEGRANAT (Granyte, Elvan, &c.).

Variety a, *Orthoclase granat.*
Sub-var. *a*, pyritous; *b*, albitic; *c*, schorlaceous; *d*, felsitic; *e*, granityte (fine grained, nearly compact granat); *f*, porphyritic granat; *g*, pegmatyte or graphic granat, &c.
„ b, *Oligoclase granat.*
Sub-var. *a*, hornblendic; *b*. titanetic; *c*, chloritic; *d*, talcose; *e*, epidotic; *f*, hematitic; *g*, pyritous; *h*, graphitic; *i*, porphyritic; *j*, gneissoid, &c., &c.
„ c, *Elvan* or *Quartz porphyry.*
Sub-var. *a*, quartzitic; *b*, orthoclasic; *c*, oligoclasic; *d*, micaceous; *e*, pyritous; *f*, hornblendic; *g*, chloritic; *h*, pyritous; *i*, nevadyte; *j*, Rhyolyte; *k*, Liparyte; *l*, rappakivi; *m*, porphyritic; *n*, compact; &c., &c.

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Variety d, *Felsyte* or *Felstone.*

Sub-var. *a*, petro-silex (highly silicious); *b*, orthoclasic; *c*, oligoclasic; *d*, minette (micaceous); *e*, hornblendic; *f*, chloritic; *g*, pyritous, with the numerous structural sub-varieties.

„ e, *Felsilyte* or *Felsite schist.*

Sub-var. *a*, quartzitic; *b*, micaceous; *c*, pyritous; *d*, ribaned, with the various other structural sub-varieties.

„ f, *Argillyte* or *Clay slate.*

Sub-var. *a*, pure or roofing slate; *b*, quartzitic or arenaceous; *c*, micaceous; *d*, pyritous; *e*, ribaned, &c., &c.

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X.—*Notes on the Geology of Easter Ross-shire.* By W. Hamilton Bell.

(Read 15th March 1883.)

My object in extending the notes which I took last summer of the geology of this district, is to interest the members of this Society and others in what I believe to be an important but greatly unexplored country in a geological point of view; and while valetudinarian motives led me to choose Strathpeffer as my headquarters for six weeks, I do not know a better starting point for those who may be more capable of using their own locomotive powers than I then was; I am also sure that the kind interest shown to me by the members of the Ross-shire Naturalist Field Club will be extended to any one who may wish to prosecute further enquires in that quarter. I owe a debt of gratitude to Mr William Morrison, Rector of the Dingwall Academy, and others, members of that Club, which I can hardly repay by thus making mention of their exceeding kindness and desire to give me all aid in their power while among them.

I need not dwell on the strata from which the celebrated waters of the Strathpeffer Spa are derived, further than by describing them shortly, as Hugh Miller has done, as "Bituminous schists of the fish beds previously existing in the neighbourhood, containing sulphates of soda, lime, magnesia, common salt, and above all, sulpherate hydrogen gas; elements which masses of sea mud, charged with animal matter, would yield as readily to the chemist as the medicinal springs of Strathpeffer." And again, "The thorough identity of the powerful effluvia that fills the pump-room, with the muddy sea-bottom, laid bare in warm weather by the tide, is, to the dweller on the sea coast, very striking; it is identity, not resemblance; and here, in smell at least, that ancient mud, swam over by the Diplopterus and Diplacanthus, and in which the Coccosteus and Pterichthys burrowed, has undergone no change. The soft ooze has become the solid rock, but its odoriferous qualities remain unaltered."

The Hill of Kinettas, which lies immediately behind the village, is almost entirely composed of a calcareo-bituminous schist, from which much of the mineral water is derived; but other springs are found in many places in the neighbourhood. No organisms of fish have yet been found, and I did not make

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search for them when Hugh Miller had been unable to trace any, after diligent inquiry.

The formations in the immediate neighbourhood are mostly the Old Red Sandstone conglomerate, and this formation extends all the way to the east as far as Dornoch Firth, although it appears that along the immediate shores of the Cromarty Firth it is the Old Red alone that is laid down. A mile to the west of Strathpeffer the conglomerate ceases, and the primary rocks appear, consisting of mica and gneiss schists, which extend right across the country to Applecross, where the quartz and red and purple sandstones come in.

From a point, locally called the "View Rock," about two miles west, and just above the Mansion of Coul, a very typical view of these different hills is to be had; you see the flat rolling hills of the gneiss in the Scatwell Hills to the south-west, and Ben Wyvis, whose huge mass and elevation of 3500 feet in the north, the latter a true gneiss mountain, with breadth of shoulders and amplitude of base enough to serve a mountain thrice as tall, but which, like all its congeners of this ancient formation, was arrested in its second stage of growth. Further west, the mica hills of Scuir Vullin and Scuir Na Vertach are seen, with their high, sharp peaked cones of 2500 feet, so typical of that formation, while, in the far west, rise the steep hills on the west side of Loch Carron, with their abrupt but square tops of the quartz, and the red and purple stones of Applecross; and again to the east, the low lying Old Red of the Black Isle running along the south side of Cromarty Firth.

There is a very interesting walk, of three miles or so, across the hills from this point to the Dingwall and Strome Ferry Railway. The ground is not difficult, the rocks are mostly mica, which appear everywhere, and the formation is very well displayed, both as to constituents and stratification, the dip and strike being almost everywhere well shown. The rocks themselves are well worth observation, being the Muscovite mica in large masses and nodules, mixed with the largest amount of garnets I have ever seen; and at and near the Glenscaigh cutting, it is quite wonderful the display of this most beautiful rock.

Passing along the railway, and near the farm house of Glenscaigh, there is a very remarkable rock, called the Raven Rock. It is gneiss, and rises almost vertically from the railway to a height of 200 feet, the railway running alongside of it for a considerable distance. Its face is worth studying, exposing as it does, the strange and distinctly marked contortions of the Gneiss, veined with Pegmatite, in some places in the most curious way. The Skye Railway is a most convenient highway for travellers, as there are few trains either way, and if you enter upon it at

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the Strathpeffer Station, you can walk along it the whole way to Garve, a distance of seven miles, with perfect safety. The cuttings are most instructive, and many minerals are found in the rocks. I found a good deal of Tourmaline, and the mica and garnets are exceedingly rich throughout its whole course.

I wish to mention here, that returning to the Strathpeffer railway station, I went up the road that is usually taken for the ascent of Ben Wyvis, and at the last house, before reaching the hill-side, at the village of Auchterneed, and close to the road, I came upon an interesting mass of stone—interesting more to the archæologist than the geologist—but which I think deserves notice. It is 16 × 12 × 3. I counted fully 100 cup markings upon it, some rather indistinct; but there are three sets of three cups most distinct, each cup in each set being connected together by a channel, and all evidently formed by the hand of man.

I did not feel able for the ascent of Ben Wyvis, but I examined the course of the River Glass, which proceeds from Loch Glass, lying at the north-east end of that hill, and which I think deserves attention. It runs in a south-easterly direction for five miles, through a bed of conglomerate, until it changes its name to the Alte Grande or Alte Graat. In its progress it forms two interesting waterfalls at a place called Coineas. The upper fall is a few yards above the other, and the water forms a pool there, over the rocky edge of which the water pours in a fan-like sheet, the edges of the sheet having cut grooves in the projecting sides of the rock face. The water of the lower falls collects in a huge bowl before it makes its final plunge down the gorge. It is only in a flood that this bowl brims over, and in ordinary states of the river the water disappears through a shaft at the bottom of the bowl, to reappear some sixty feet down in the pool, which runs on then as the river; and sticks thrown in above the first fall, are found at this place, without having run the gauntlet of the second fall.

After the falls, the river runs through a deep deposit of boulder-clay, in a channel with scaurs fifty feet high on both sides, until it reaches an extraordinary fissure, locally called the Black Rock of Evanton. This rift begins about two miles from Evanton, and occurs on the Estate of Novar. It runs through a channel, at first not above fifty feet deep, but this afterwards increases to a depth of 150 and 200 feet. It is the most weird place I ever saw; the rocks have a perpendicular descent, and so narrow that a tree falling on one side finds its resting-place on the other. Both sides of the river are covered with trees of all kinds, which continue all the way down for two miles to the sea. The proprietor has kindly prepared a footpath all the way, and the water is altogether invisible except at curves of the stream,

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where barriers of wood are erected, enabling one to look down with safety upon the dark abyss, and see the water surging below in innumerable pot holes and grooves cut by the stream. It was a fine evening when I was there, and it was a beautiful yet grand sight to see the sun glinting among the ferns and wild-flowers springing up on the precipitous sides among the trees which grew all the way down to the water's edge.

This chasm lies at the very confines of the junction between the conglomerate and the adjoining gneiss, but I found it was altogether in the conglomerate that the rift had been formed. This formation seems liable to be fissured in this way, as the whole progress of the stream seems to have run through channels worn by itself.

I was much struck with the whole of this chasm, which seemed to me to resemble on a very small scale the canons of Colorado; and as sand is there the factor of erosion, I thought that here the same factor had been at work. Indeed I found that where the water flows out into the open bed below, the sand deposited there, was enormous in quantity. In thinking over it, I came to the opinion that the boulder-clay must have filled the rift, and on returning home I was confirmed in this by what Hugh Miller says of this very place in his "Cruise of the *Betsy*," where he says, "In all probability (this fissure) has been caused by a fault in the conglomerate, similar to many of those faults which occur in the coal measures of the southern districts, and which we find occupied by the trap. But in this northern district, where traps are unknown, it must have been filled up by the boulder-clay, or some still more ancient accumulation of debris, and when the sand had risen, and when the streams, swollen into rivers, flowed along the hollows which they now occupy; the loose rubbish would, in the lapse of ages, gradually wash down to the sea; as the stones thrown down from the fields above were washed down in a later time, and thus the fissure would ultimately be cleared out." This fissure which is thus so interesting to a geologist must be equally so to the botanist. Down the whole two miles, the sides are one mass of ferns and wild-flowers, growing in the dense woods which line its course; only it would be an exploration of peril, as the face of the cliffs and soil is almost vertical; so much so, that while Hugh Miller speaks of having warped himself up the face at great risk, he was one who all his lifetime had been associated with such perils, and I, for one, would not like to risk the danger.

I was favoured while in this district by being asked by the Ross-shire Naturalist Field Club to join one of their excursions to examine a fish-bed deposit near Ederton, on the Dornoch

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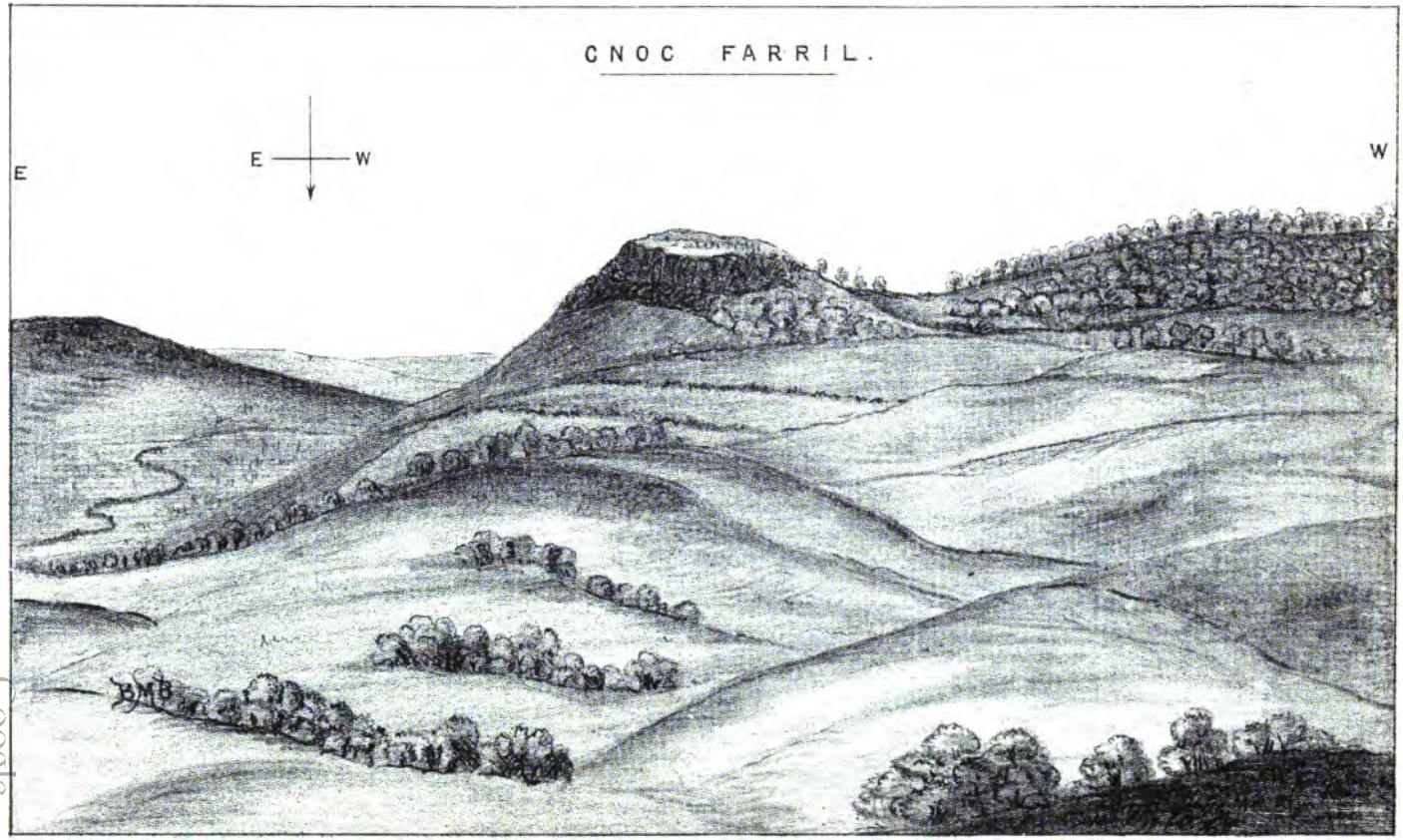

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Firth, and a large party of us left Alness one day to drive over there, a distance of sixteen miles. The road ascended for a considerable distance past Ardross Castle to the River Rory, where some river terraces are exposed. By the Ordnance Map these terraces occur at a height of 605 feet above sea-level. The River Rory takes its rise in the hill Beinn Tharsuinn, 2270 feet high, about five miles off; and where the road crossed the stream, the terraces were visible. There are two, and are formed on only one side of the stream at that place. The lowest one is quite exposed to view throughout, as a scaur in the river-side. These terraces are composed of river drift, and those of the party who were acquainted with them, said there was no appearance of striated stones in the drift. This escarpment was about seventy feet high, and then a terrace of about twenty feet, which again was surmounted by another escarpment of less height, and then a second terrace covered with heather on the level beyond, after which the hill assumes the usual aspect to the north. We had not time for more minute examination, as we were bound for the fish-bed further on; but I am informed that these terraces continue up the stream for some miles from where we crossed it, and from thence down the stream towards the sea, where it takes the name of the Balnagown River, and that the Castle of Balnagown, the seat of Sir Charles Ross, is built on the last terrace.

Leaving this, we proceeded onwards to the Inn at Altnamain, the half-way house between Alness and Bonar Bridge on the Dornoch Firth. The elevation here is 710 feet above sea-level, and close to it is the Alt Muidh Blair River, which rises in Loch Muidh à Blair about two miles west, that loch lying at the foot of the hill called Cnoc Muidh à Blair. Descending along its course, we came to a gravelly escarpment in the Old Red Sandstone, and at this spot the river is the distinct boundary between the primary formation and the Old Red. We were rewarded by finding numerous nodules in the shale of the escarpment, which is about twenty feet high. Almost all the nodules we broke up contained fossils of Coccosteus, some in perfect preservation. We found some tourmaline, and some pieces of very fine calcareous spar in the stream, and around it. The river is not a large one, and there is a sharp bend just at the place where the fossils were found. At this point the stream is eating out the bank very fast; and I understand that the deeper the bank is cut, the more prolific in fossils the deposit becomes.

I could not be at Strathpeffer, and in such close neighbourhood to the vitrified fort of Knock Farril, without becoming interested in the vexed question of these forts; and although the question is more for the archæologist than the geologist, I trust this Society will not consider it out of place if I allude to the

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matter, although I may trespass to a certain extent upon subjects than are not generally brought before us. I wish also it should be understood that I am giving my own observations on the subject as regards *this fort*, which is the only one I have inspected, except that of Craig Phadrick, which I visited many years ago.

Knock or Cnoc Farril lies on the east of a hill composed of Old Red Sandstone conglomerate. Its summit is 579 feet above the level of the sea, according to the Ordnance Map, and nearly so above the level of the adjoining country. The hill begins about two miles west of Dingwall, in the Vale of the Peffer, and continues to run westward for two miles, ending in an almost precipitous bluff, called Cnoc Mor, 882 feet high. This ridge has the local nomenclature of the Cat's Back, Cnoc Mor being the head, Cnoc Farril the tail or rump. The hill is covered with trees along the summit, and these, seen against the sky, give it the appearance of a cat in a rage. The conglomerate here ends its westward limit, having run all the way from the Dornoch Firth, except where the fringe of pure Old Red, of small extent, runs along the shores of the Cromarty Firth. Cnoc Farril is situated at the east end, with a perceptible separation between it and the west part. It stands almost alone. It is slightly fringed with trees, but the top of the hill is quite bare, which gives a good opportunity for taking in the whole at a glance. It is very steep in its north slope, certainly not less than an angle of 45°; and one feature of the hill, to which I would call especial attention is, that at this side, a face of the conglomerate is exposed, which runs for 100 feet along the side of the hill. This exposed face is at least fifty feet high, and approaches to the very top with an angle of 30°, and probably cropped out there, ere the soil was formed above. The east side is not so steep, nor is the south, while from the west, and at the place where it is perceptibly separate from the Cat's Back, the slope is so gradual that carts could easily ascend, and it is here that the entrance to the fort must have been.

The summit of the hill is 120 feet long and 40 feet broad, and is covered with the richest verdure; indeed this verdure is so apparent that it is noticeable from a great distance, contrasted as it is with the brown heath-covered hill adjoining. There are the remains of two wells near the summit, one of which used to be full of water till within the last few years, and the grass is of such excellent quality that numerous cows and cattle are always pastured there. There seems to have been a gateway at the west end of the road mentioned, and then the ramparts begin. These ramparts continue round the top of the hill, with very

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little space between them and the slope of the hill. They are generally from five to eight feet high, but are in many places much broken down by the weather.

I found the ramparts to consist of vitrified matter, very difficult to break up, the constituents being almost entirely of the native conglomerate, which is composed of stones, large and small, of gneiss, quartz, and micacious sandstones, bound together with the natural cement of the conglomerate, viz., peroxide of iron, silica, sand and lime. The soda and potash of these rocks, along with the alkali of the wood, also must have caused the fusion of the conglomerates, and were flux, sufficiently strong to have produced the vitrification before me. In some places the outside of the mass was less fused, and presented the appearance of ginger beer bottle ware, the fusion being not thicker than one's finger-nail; but generally the vitrification extended inwards to the extent of nearly a foot, where it was visible in the broken mass. The vitrescence ran in all directions, and filled up the interstices with white, cream-like matter. I am satisfied that here the vitrified mass was the conglomerate, and as I before mentioned, I believe that the conglomerate had *cropped out to the surface of the hill* ere it was covered by the soil as at present; that fusion had been applied to the broken-down mass; and that fires applied to it, under the influence of strong winds, had been the factor of the vitrifying process, in the same way as it was found that the basalts at the top of Arthur's Seat, on the occasion of the Queen's first visit, had been fused to the depth of an inch by the bonfires then kindled there.

Throughout the whole ramparts I found it impossible to ascertain the depth of fusion in the walls further than a foot or so; and it seems to be one of the points to be ascertained for the settling of the question whether the vitrification extends right through the wall. I find that Williams, in his pamphlets, had endeavoured to do so, but the result is not given.

I had previously visited Craig Phadrick, near Inverness, and have specimens of the fused material, which was also conglomerate. I found in the heart of some of the pieces there, wood charred into charcoal, which seems to point to that as the agent employed; and at the period when these forts must have been built, there could have been no lack of that material. I have found no wood in the vitrified portion of Cnoc Farril. At the extreme eastward point of the hill there are appearances of a double wall, and there the fort would be more easy of access by the assailant than at the north and south.

This is all I have to bring forward in a geological point of view, and again I say that, in my opinion, the conglomerate had been used here for the building of the ramparts, and that it was

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sufficient of itself, in those rude times when Armstrong guns were not in existence, to form a strong protection to the defenders; and I was the more confirmed in this view from finding that Williams and Dr Samuel Hibbert state generally that the vitrified forts in the north have been formed of conglomerate—Williams stating that the "Tap o' Noath" Fort and Craig Phadrick, as well as others, have all been built of the same material, and Hibbert, that where conglomerate was not used the vitrification was not so complete.

I was very frequently on the hill, and generally had with me Hugh Miller's "Cruise of the *Betsy*," in which he gives a very good resumé of the four views mentioned there. I went over them on the spot, and often examined the whole country around. The prospect is very extensive, and on a clear day I saw the Moray Firth as far as the Birne of Cullen, back to the hills beyond the Spey. Craig Phadrick was within easy ken, and always visible. The valley of the Caledonian Canal was shut out by Craig Phadrick, but the whole way to the west coast was visible—Scuir Vullin and Scuir Na Vertach again appearing. Miller gives four views of the theory of the vitrifaction of these forts, viz.:—(1) Pennant—That the agency was volcanic. Of this nothing need be said nowadays; (2) Williams—That it was intentional for the strengthening of the ramparts; (3) Lord Woodhouselee—That it was caused by the enemy setting fire to the wood of which the ramparts were partly composed; and (4) Sir George Mackenzie of Coul—That the fusion had been caused by signal fires, lighted up to give notice to the surrounding country of the invasion of an enemy. Mr Miller is disposed to give effect to a combination of the views of Williams and Sir George Mackenzie.

After a good deal of thought upon the subject, I venture to give vent to an idea on the question, which occurred to me one day with the whole view of the country before me, and these views of Miller's in my mind. It was this, that the origin of the vitrifying agent had been accidentally discovered by the natives in old times, observing the effect their signal fires had upon the rocks, used for the backing of their fires; and that, like so many other discoveries accidentally made, they then employed that factor for the purpose of fusing the ramparts, they were induced to build as protection from attack. When I returned home I went pretty deeply into the literature of the question, and I must say that from all I have read, this view is not only confirmed, but seems to have occurred to those whose papers I read and who, I think, have the best of the question.

The subject is most fully stated by Dr Samuel Hibbert

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in his report to the Archæological Society in 1828. He goes very fully into the views of all those who had written up to that time, and gives no support to the volcanic origin of the hill on which the forts were erected. He quotes at length the views of Dr Anderson of Monkshill, Aberdeen, who, in reporting to the Antiquarian Society of London, 27th November 1777, says "that through all the northern parts of Scotland, a particular kind of earthy iron ore, of a very vitrescible nature, much abounds. This ore might have been accidentally mixed with some stones, at a place where some great fire was kindled, and being fused by heat would cement the stones into a solid mass, and give the first hint of the uses to which it might be applied. A few experiments would satisfy them of the possibility of executing at large, what had been accidentally discovered in miniature. The knowledge having been thus obtained, nothing seems more natural than to apply it to the formation of the walls of the place. Having thus chosen a place they would raise a wall around the area, building the outside as firm as they could with dry stones, one above the other, the interstices being filled up with the vitrescible iron ore, and supported by a back of loose stones." Dr Hibbert remarks that this is not true as to the agent, that agent being proved to be the alkaline ingredients of granite, gneiss, mica, slate, hornblende, and sandstone, which are all more or less fusible in proportion to the felspar contained therein.

Dr Hibbert states the views of Sir George Mackenzie, who says that in the eighth century, after the Scots had defeated the Picts, a regular system of beacon fires was carried on throughout the north of Scotland, and specifies twenty established between Banff and Dingwall and Fort Augustus, on the great central valley. Dr Hibbert also quotes a report of Dr Milligan to the Manchester Philosophical Society, in which Dr Milligan states that there were forts near Huntly connected with the east coast from Kinnaird Head to south of Dee; more of them from Kincardineshire to Tay; others prolonged from Stonehaven and Dundee to Dunkeld and Crieff; to the west, at Bute, Cantyre, Islay, Loch Etive, Loch Sunart, Fort-William, Arisaig, all showing these forts as having been used as beacon fires. Dr Hibbert gives his own conclusions (thirteen in number), mostly dealing with those advanced by others which he considers not tenable, and says, lastly, that nothing can be more satisfactorily established than that the vitrifaction of these forts has been incidental and not designed in the first place, and that the term to be employed in designing them should be "vitrified sites," not "vitrified forts."

I may mention, as an adminicle of evidence on this point and

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no further, in so far as Cnoc Farril is concerned, that after full enquiry I find that many of the existing Gaelic speaking population of the neighbourhood term it "Cnoc Fairilees," and that, taking this as the nearest approach to the name as pronounced, the best authorities on Gaelic names and Gaelic topography consider it as composed of two words, "faire," watching, and "lios," which is now generally a term for a garden, but formerly meant any fortified summit. It appears in the beginning of topographical names, as in "Lesmurdie;" in the end of names it takes the question form of "Leasa." Fairilees is, therefore, the "watching fort."

I can only say for myself, in conclusion, that I consider the signal theory, as the introductory origin of these vitrified forts, to be the most satisfactory; while from the fact, that many of the known forts, such as those at Burntisland and Bute, are not on elevated platforms, I think that the vitrifying agent had been applied to them for the strengthening of the forts, after the effect of vitrescence had been ascertained in other quarters; and I can quite realise in my mental vision, what was patent to my actual vision on my post at Cnoc Farril; how that when these sites were used as signals of danger during the wars of the Picts and Scots in the eighth century, the natives had taken advantage of the discovered power of vitrifying as forts, what had only been used as signal sites; and that as signs of the approach of the Vikings of these days were seen; the fires would be lighted, and notice of the danger flashed, like the heliograph of the present day, from the forts at the mouth of the Moray Firth to Craig Phadrick, from thence to the corresponding forts on the great central valley in the west, while Cnoc Farril would receive its signal as the northmost site; and I can imagine I see the natives teeming down the Ness Valley to Craig Phadrick to meet the foe on the Moray Firth, while the country would be alive with the defenders descending from Auchnasheen and the west of Ross-shire, down to Cnoc Farril, all eager with the determination to resist the ruthless invaders; while their courage would be heightened for resistance by the knowledge that they would now have a post of strength, made stronger by the new discovery, which would be more capable than ever of sheltering their cattle and their goods, their wives and families, so precious in their eyes—more precious than their very lives.

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XI.—*Notes on the Fossils of the First Gilmerton Limestone.* By W. TAIT KINNEAR and W. ANDERSON.

(Read 15th March 1883.)

As hitherto little or nothing has been written with regard to the fossiliferous contents of the first Gilmerton Limestone, the present paper is an attempt to lay before the Society the results of our work in that direction. The limestone in question is seen in section a little to the north of the village of Gilmerton in the form of old quarry workings, extending in the line of strike for nearly half a mile. When these workings were last in operation we do not know. If we begin at the north end and proceed southwards, the first thing that strikes our eye is a thick compact limestone. Proceeding southwards we gradually perceive this to be overlaid by a series of more or less soft limestone shales, closely approximating in character to the limestone below it. These shales are in their turn overlaid by a series of blackish lime shales which are very fossiliferous. These latter shales, if we still keep going in the same direction, are seen to be overlaid by thin beds of sandstone and sandy shales. A little to the south of the Lasswade road, as it nears Gilmerton, the quarry workings come to an end, the highest bed in the series being a red sandstone. A limestone considered to be the same as this one is seen at a railway cutting on this side of Loanhead, and not far from Straiton brickworks. The striking feature here is the very thick red sandstone which overtops it; but if we remember that the overlying beds thicken as we proceed southwards, and that a red sand, similar though less thick, is seen near the northern end of the quarries, this fact is not so astonishing. All in all the result of our investigations has been the bringing to light of forty-three genera and eighty-five species and varieties. Two species are added on the authority of others. To the collector the Gilmerton limestone is a disappointing field for his labour. The fossils are as a rule poorly preserved, and in many cases very fragmentary. This applies more especially to the bivalves, of which there are a vast number in certain parts of the beds. The Polyzoa seldom show the celluliferous face on which one has to rely for the discrimination of species. In a few cases the Brachiopoda are well preserved, as Lingula, Chonetes, and Productus. This state of matters is little compensated by weathering. In some districts limestone shales rich in fossils are best worked when the weather has reduced

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them to brittle fragments; but the Gilmerton limestone offers no such facilities. Looking now at the whole series from top to bottom we notice that the thick compact limestone at the base is either non-fossiliferous or nearly so. Immediately above the limestone come the limestone shales, some of which are hard and others much softer. These shales yield a good number of fossils, but none in a good state of preservation except the Polyzoa, some Archæocidaris spines, and *Chonetes polita*. The blackish limey shale which overtops the limestone shales is full of fossils, especially the Lamellibranchiata, which occur in enormous profusion in a good state of preservation, but often tantalisingly fragmentary. The sandstones overtopping the whole series are non-fossiliferous. We will now take up the fossils group by group.

Echinodermata.

This group includes the well-known Archæocidaris, with its species *A. scotica* and *A. Urei*. They occur as spines, interambulacral plates, and portions of the masticatory apparatus. They are found throughout all the shales and in all stages of preservation. In some cases the plates and spines are scattered over the same slab.

We can say nothing definite with regard to the Crinoids. Throughout the shales the stems and ossicles of Crinoids may be seen on the weathered surfaces; but as the forms of these stems are so variable it would be rash to commit oneself as to their identification. The limestone exposed further south of the Loanhead Railway shows more Crinoid remains than this one. At that locality we picked several small calices out of the weathered surface, but we have not had them identified.

Annelida.

The remains of Annelids are seldom met with in the places where we have examined this limestone. *Serpulites carbonarius*, which occurs in some shales in such abundance at Roscobie and Ardross Castle, in Fife, is very rarely seen. The only other species is doubtful—*Spirorbis ambiguus?* The latter Annelid has been noted by us on the shell of *Edmondia unioniformis*.

Crustacea.

Among the Crustacea we include three genera Entomoconchus? Leperditia and Dithyrocaris. The limestone shales do not impress one as likely to yield crustacean remains. The specimen of Dithyrocaris consists of one valve, and that in no very good state of preservation. Whether or not any Ostracods, such as *Bairdia*, *Kirkbya*, or *Cythere* occur in the limestone shales, we

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cannot say, as these shales never weather into a soft, crumbling mass.

Polyzoa.

Five genera and twelve species of Polyzoa have been noted by us. The genera include Fenestella, Actinostoma, Glauconome, Rhabdomeson, and Cynocladia. The genus Fenestella includes the most species namely, *F. ejuncida*, *F. tenuifila*, *F. tuberculo-carinata*, *F. quadridecimalis*, and *F. multiporata*. Of these, *F. multiporata* and *F. tuberculo-carinata* are the most common forms. Rhabdomeson, a fossil rather common in some limestone shales, is rare. We have only noticed it twice, yet its form is so marked that it is impossible to mistake it. *Cynocladia carbonaria* is an exceedingly common fossil in the blackish shales, lying above the main limestone. Glauconome, of which we have noted three species—*G. elegans*, *G. laxa*, and *G. stellipora*—is not uncommon in the shales, lying immediately over the thick limestone. It occurs in a fair state of preservation, and sometimes shows the cells. The abundance of Polyzoa is one of the chief features of this limestone, and the collecting of them is not a very difficult matter, as the edges of the "fronds" can be traced on the weathered surface.

Brachiopoda.

We record six genera, eleven species, and three varieties of Brachiopoda. The genera include Productus, Chonetes, Lingula, Rhynconella, Strophomena, and Terebratula. Productus is the most numerous as regard species, of which we have noted the following:—*P. longispinus*, *P. muricatus*, *P. semireticulatus*, *P. scabriculus*, and *P. semireticulatus* var. *martina*. All these are more or less found in the limestone shales, and do not occur as far as we have noted higher up. *Rhynconella pleurodon* and *R. pugnus* are only to be obtained in the shales at the very top of the section. They are in pretty good preservation, and present a silvery white exterior. *Chonetes polita* is a very common fossil in a soft bed near the bottom of the series. The species of Terebratula include *T. hasata* and *T. sacculus*, along with a variety. They are all very much crushed, and are in a very poor state of preservation. *Lingula mytiloides* occurs pretty much throughout the whole of the shales. *Lingula squamiformis*, a species common in other localities, has never been noted by us. On the authority of Mr J. Henderson we include in our list the important genus Crania, of which he obtained a specimen in this limestone.

Lamellibranchiata.

The Gilmerton limestone will perhaps compare favourably

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with any limestone in Scotland in regard to its bivalves. From the top of the shale to the bottom they occur everywhere. Nearly every bit of shale yields its quota of Aviculopecten, Edmondia, or Modiola. In all, we have noted fourteen genera and thirty-six species. The genera include Aviculopecten, Edmondia, Axinus, Modiola, Cypricardia, Nuculana, Sanguinolites, Myacites, Posidonomya, Leptodomus, Venus, Pecten, Pteronites, and Arca. The commoner genera are Aviculopecten, Edmondia, Modiola, Nuculana, and Cypricardia. The genus Aviculopecten yields a large number of species, twelve in fact, some of which are very common, as *A. dissimilis*, *A. arenosus*; *A. granosus*, and *A. plicatilis*; and some rare, as in *A. flexuosus* and *A. interstitialis*. The genus Cypricardia is represented by five species and a variety. It includes *C. rhombea*, *C. striato-lamellosa*, *C. acuticarinata*, *C. glabrata*, and *C. cylindrica*. None of these are very common. Modiola is represented by *M. lithodomoides* and *M. lingualis*. Of the former good specimens may be obtained in the topmost beds. Axinus is represented by three species—*A. carbonarius*, *A. deltoideus*, and *A. axiniformis*. They are nearly all confined to the lower beds, and are often not well preserved. Edmondia is one of the commonest of the bivalves, and is represented by *E. rudis* and *E. unioniformis*. They occur pretty much throughout the whole of the shales. The exteriors of all the bivalves are exceedingly brittle, and the task of collecting them is often very annoying. Sometimes you may get a specimen showing a part of the shells and the wings, as in Aviculopecten, and wanting the ventral margin. Then you get another showing a good ventral margin and no wing. So difficult is it to obtain reliable specimens that in some cases scores have to be flung away before a good, trustworthy specimen is obtained.

Gasteropoda.

We have noted five genera and nine species of Gasteropods. The genera include Macroheilus, Pleurotomaria, Loxonema, Bellerophon, and Naticopsis. *Macroheilus acutus* is a common species in the upper beds. Loxonema we have only noted once, and that in the shape of a cast. Pleurotomaria and Naticopsis are not often met with. Among the Heteropoda we have Bellerophon represented by four species—*B. Urei*, *B. decussatus*, *B. Yvanii*, and *B. striatus*. The Gasteropods occur pretty much throughout the whole of the shales, but in comparison with the Polyzoa and Lamellibranchiata their numbers are scanty.

Pteropoda.

The Pteropod *Conularia quadrisulcatus* we obtained from the topmost beds, and in the usual crushed condition.

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CEPHALOPODA.

The Cephalopods include three genera and six species. The genera are Orthoceras, Cyrtoceras, and Nautilus. Three species of Orthoceras occur—*O. cinctum*, *O. cylindraceum*, and *O. attenuatum*. They occur pretty much throughout all the shales. *Cyrtoceras unguis* hails from the lower beds, and is usually found in a broken condition. *Nautilus quadratus* and *N. subsulcatus* occur freely, especially the former in the shales immediately above the thick limestone.

SELACHII.

Two specimens of *Petalodus Hastingsiæ* have been found, and a new species of spine, *Tristychius Fimbriatus*.

INCERTAE SEDIS.

Of several oval striated impressions not uncommon in the shales, Mr John Young says—"I cannot make anything of these curious impressions, they are quite new to me. There is no structure to show whether they are due to plants or some soft bodied organism. The *Cypricardia rhombea* shows that the strata was marine."

GENERAL CONCLUSIONS.

The great distinguishing features of the First Gilmerton Limestone are the great abundance of bivalves and Polyzoa, the comparative scarcity in numbers of Brachiopods, and the total absence of corals of any description. Slight differences may be noticed between the higher and lower beds, but only those who have investigated the limestone for some time can observe them. The Productidæ are found usually at the bottom, and the bivalves attain their highest development, numerically and specifically, at the top shales. *Cynocladia carbonaria* occurs at the top as far as we have observed. To the beginner no limestone appears, at first sight, so unfruitful as a sphere of investigation, but upon continued working it is soon found that there is a plentiful if not a well-preserved store of fossiliferous remains.

We have to return unbounded thanks to Mr John Young of the Hunterian Museum, Glasgow, for the trouble he has taken in going over our specimens. No carboniferous invertebrates, especially univalves or Polyzoa, could go into more competent hands for naming. We have also to thank Mr Thomas Stock and Mr John Henderson for help and advice given us while examining this Limestone.

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LIST OF FOSSILS from the First Gilmerton Limestone.

Echinodermata.

Archæocidaris Urei, Flem.
" Scotica, J. Young.
Scattered Crinoid stems.

Annelida.

Serpulites carbonarius, J. Young.
Spirorbis ambiguus ? Flem.

Crustacea.

Entomoconchus ? (Cast.)
Leperditia Okeni, Münst.
Dithyrocaris spec.

Polyzoa.

Glauconome elegans, Y. & Y.
" stellipora, Y. & Y.
" laxa, Y. & Y.
" recticarinata, Y. & Y.
Actinostoma fenestratum, Y. & Y.
Cynocladia carbonaria, Ether.
Fenestella ejuncida, M'Coy.
" tenuifila, Phill.
" multiporata, M'Coy.
" tuberculo-carinata, Ether.
" quadridecimalis, M'Coy.
Rhabdomeson gracile, Phill.

Brachiopoda.

Chonetes polita, M'Coy.
Lingula mytiloides, Sow.
Productus longispinus, Sow.
" muricatus.
" semireticulatus, Martin.
" semireticulatus var. Martini, Sow.
" scabriculus, Martin.
Rhynconella pleurodon, Phill.
" pugnus, Martin.
Strophomena analoga Phill.
" analoga var. distorta, Martin.
Terebratula hastata, Sow.
" hastata var. Gillingensis, Dav.
" sacculus, Martin.
Crania (J. Henderson).

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Lamellibranchiata.

Monomyaria.

Aviculopecten arenosus, Phill.
„ deornatus.
„ dissimilis, Flem.
„ flexuosus, M'Coy.
„ granosus, Phill.
„ interstitialis, Phill.
„ Knockonniensis, M'Coy.
„ ornatus, Ether.
„ papyraceus, Goldf. (Gall).
„ plicatilis.
„ plicatus, Sow.
Pecten Sowerbii, M'Coy.
Posidonomya vetusta, Sow.
Pteronites persulcatus, M'Coy.

Dimyaria.

Arca Lacordaireana, De Kon.
Axinus axiniformis, Phill.
„ carbonarius, Portl.
„ deltoideus, Phill.
Cypricardia acuticarinata, Armstrong.
„ cylindrica, M'Coy.
„ glabrata, Phill.
„ rhombea, Phill.
„ striato-lamellosa, De Kon.
Edmondia rudis, M'Coy.
„ unioniformis, Phill.
Leptodomus costellatus, M'Coy.
„ sulcatus.
Modiola divisa, M'Coy.
„ lingualis, Phill.
„ lithodomoides, Ether.
Myacites sulcata, Flem.
Nuculana attenuata.
Sanguinolites plicatus? Portl.
„ tricostatus, Portl.
Venus parallela.

Gasteropoda.

Pleurotomaria Yvanii, Lév.
Loxonema spec.
Macroheilus acutus, Sow.
Naticopsis caniculatus, M'Coy,
„ variata, Phill.

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Heteropoda.

Bellerophon decussatus, Flem.
„ Dumontii, D'Orb.
„ striatus.
„ Urei, Flem.

Pteropoda.

Conularia quadrisulcata, Sow.

Cephalopoda.

Cyrtoceras unguis, Phill.
Nautilus quadratus, Flem.
„ subsulcatus, Sow.
Orthoceras attenuatum, Flem.
„ cinctum, Sow.
„ cylindraceum, Flem.

Selachii.

Petalodus Hastingsiæ, Owen.
Tristychius fimbriatus, Stock.

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XII.—*The Mineral Albertite and Strathpeffer Shales.* By Wm. Morrison, M.A., Dingwall Academy.

(Read 15th March 1883.)

The valley of Strathpeffer occupies the eastern extremity of one of the great troughs which deeply score the Northern Highlands from sea to sea. It lies as a tongue of Old Red running into the region of altered silurian rocks. The southern boundary of the Strath, for about two miles, is formed by a ridge of Old Red Sandstone and of conglomerate, rising as at Knock Farril to 579 feet, and overlying the Old Red, which, onwards to the head of the Cromarty Firth, shows its truncated edges dipping to the south-west at an angle of 45°, thus making the southern flank of the valley an almost precipitous rampart. The face of Knock Farril looking towards the Strath presents, according to Ruskin, the most beautiful instance of the angle of repose to be anywhere seen.

The northern side of the valley, on the other hand, rises with a gentle ascent to a height of from 900 feet to 1100 feet, as on Tulloch Hill, and this general height is maintained by the whole northern boundary ridge to the head of the valley.

This ridge is composed of an aluminous shale rock, overlaid by flags of micaceous sandstone and compact limestone, having a general dip to the south-west at an angle of about 25°. These calcareous flags overlie the shales, and are very much broken up by frequent lines of cleavage running, in general, from east to west.

These facts are pretty well known, but not so those, however, regarding a remarkable mineral found associated with these shales, and provisionally named "Albertite." Attention was chiefly drawn to this "coal" when, in the course of making a cutting for the Highland Line near Dingwall, several veins of the mineral were exposed. These veins are found not only in the sandstone, but even in the conglomerate, which to a depth of about 200 feet overlies it. I found the veins in all cases to be nearly vertical (at angles of 70° and 80°), and also to occur in slickenside faults of the conglomerate which run east and west. Indeed, with the exception of two or three, all the faults run in that direction. The veins vary in thickness from an inch to less than that of writing-paper. They preserve the same peculiarities of thickness, direction, and straightness of edge-line, no matter whether the veins are found in joints of large blocks of sandstone or in the confused mixture of this conglomerate

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composed of boulders, large and small, of quartz, gneiss, and quartzite imbedded in a matrix of sand, strongly cemented in some places by infiltrated carbonate of lime and iron. The faults in the conglomerate in the railway cutting near Dingwall occur at intervals of 30 yards, and are as clean and sheer down as if the entire mass were cut through by some gigantic knife.

Strange as the occurrence of an organic mineral in conglomerate may be, stranger still, and of far more import, it is to find this same mineral imbedded in *gneiss!* I happened lately to see in a copy of "Anderson's Guide to the Highlands" it stated that "Anthracite coal has also (1847) been discovered on the ridge north-west of the Dun of Castle-Leod imbedded in primary *gneiss* rocks, a most unusual occurrence." I had heard of borings for coal made on the banks of the river Sgiach, by order of the Duke of Sutherland; but I was not previously aware that "coal" was found in gneiss not far from this quarter. After some search I came upon three old workings, above Castle-Leod, at heights of from 700 feet to 1100 feet above sea, on the face of the hill opposite that on which the Skye Railway runs, and at about ten minutes' walk from the gorge of the "Raven's Rock." The rock is there altogether crystalline from about 200 yards west of Strathpeffer Station on to Loch Carron. In these workings I found undoubted "albertite," and, as elsewhere, it was in vertical veins. The veins were of about the usual thickness, from $\frac{1}{8}$ to 1 inch. The quantity found when worked was extremely small. The local blacksmith, fifty years ago, used the greater part for the forge when he was "hard up" for coal from the south.

From the specimens sent, it will be observed that the rock in which this mineral is embedded is a highly micaceous gneiss in some instances, in others a gneiss of a more crystalline structure. The gneiss in some sections on this hill shews beautiful instances of the contortions and flexures characteristic of that rock. Like "straws and flies in amber," it may well be matter of wonder how (in the commonly received belief, regarding the absence of fossils in primary formations) we can account for the presence of an undoubted hydrocarbon imbedded in such rocks. To me it is as puzzling as is the presence of hydrocarbons in the structure of comets.

Through the kindness of Major Mackenzie of Findon, on whose estate some of this Albertite is found, I am enabled to lay before you a detailed analysis of this mineral made for him by the late Prof. Penny of Glasgow. The name "Albertite" is given to the mineral on account of its supposed resemblance to a mineral found in Albert County, New Brunswick. See Dawson's "Geology of Acadia" for a description of that mineral.

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In some respects Albertite and Whitby jet agree. Like anthracite, the fracture of albertite is conchoidal. Unlike jet, it is acted on more or less by the usual solvents for bituminous substances. Jet, strictly speaking, is slightly acted upon by carbon disulphide, but albertite is softened throughout by this solvent. According to Professor Penny, albertite bears a strong resemblance to the Torbanehill mineral in its chemical properties. Indeed a comparison of the analysis given in Rammelsberg's "Handbuch der Mineral Chemie" of Boghead coal with that of "albertite," as made by Penny, would almost lead one to the belief, making a deduction for the inorganic part of the shales in this quarter, as in the case of the Boghead coals, that the organic compound in both cases is similar. I was thus led to the idea that the mineral albertite found here is but an indurated form of petroleum injected from a liquid reservoir in the bowels of the earth, and that the subsidence, "caving in," which caused the cracks, at the same time filled these cracks with the liquid hydrocarbon. This must have been originally formed from the dry distillation of the shales beneath in the case of that found in the conglomerate and sandstone, but cannot account for its presence in the crystalline rocks of Castle Leod.

The specific gravity of albertite shows it to be the lightest coal known.

Water	1000
Albertite	1089
Coal pitch	1267

Solvents :—

Ether	4·5 per cent. of Bitumen.
Naphtha	6·6 „ „ „ „
Benzole	6·6 „ „

A ton of albertite gives

7 cwt. 53¾ lbs of coke.

In 100 parts of albertite there is of

Volatile matter	62·00
Fixed carbon	37·00
Water	0·60
Ash, sulphur	trace

Detailed Analysis.

Carbon	79·75
Hydrogen	8·12
Nitrogen	1·63
Oxygen	10·30
Ash	0·20

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Professor Penny remarks that there is in the mineral an unusually large proportion of hydrogen, and equal to Torbanehill coal. It contains more nitrogen than that coal.

In Boghead coal from Rammelsberg. Analysis:—

Organic.		*Inorganic.*	
Carbon	80·56	Silica	54·26
Hydrogen	12·17	Alumina	39·39
Oxygen	5·82	Ferric oxide	5·04
Nitrogen	1·03	Calcium oxide	1·13
Sulphur	0·42		
	100.00		99·82

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XIII.—*Notice of Columnar Basalt at Ladeddie Hill, near Pitscottie, Fife.* By RALPH RICHARDSON, W.S., F.R.S.E., *Vice-President.*

(Read 19th April 1883.)

NOT far from Magus Muir, where Archbishop Sharpe was murdered in 1679, stands the eminence known as Ladeddie Hill. It attains a height of 600 feet; but about a hundred feet below the summit occurs a quarry of basalt, now being worked for road metal. My attention was directed to this basalt by seeing it lying on the roadsides of the district in curious pig-iron-like bars, which proved to be fragments of the columnar basalt I shall describe immediately. I was informed that these fragments were derived from a quarry on Ladeddie Hill, and on proceeding there was surprised at the beauty and regularity of the columnar structure. On ascending to the quarry I found that it presented a fine example of fan-shaped columnar basalt; and as I watched this exquisite work of Nature, so interesting and so rare, being blasted away bit by bit, I could not help wishing that some such statute as was passed last year to protect Ancient Monuments were passed to protect from destruction beautiful and instructive objects of Nature such as this. Thousands of travellers annually visit, wonder at, and admire the columnar basalt of the Giant's Causeway, Fingal's Cave in Staffa, or the "Kilt Rock" in the Isle of Skye; yet here in Fife a most interesting and beautiful specimen of the same singular rock-structure is being broken up for road metal. My visit occurred during July 1882, and then the operations of the quarrier had removed a very large mass of the basalt. They laid bare, however, the columnar structure of the rock in a very effective although very ruthless manner. I shall now describe the section as exposed last July at the quarry.

The road forming the entrance to the quarry on Ladeddie was cut through about twelve yards, in length, of *volcanic ash*, apparently unstratified, of a dark colour and coarse grain, and laden with lapilli and volcanic bombs, evidently discharged from some neighbouring volcano or volcanic fissure. Then we passed for about four yards through *basalt* of ordinary amorphous and non-columnar structure. Next followed about six yards in length of *basalt* of regular columnar structure in long, shapely columns, some of them four yards in length, and all of considerable beauty. These columns were almost invariably five-sided, whereas at the Giant's Causeway I observed that the prisms of the basalt on the beach were variously sided, some being four-sided and others five, six, seven, or eight-sided.

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A little observation of the columnar basalt at Ladeddie showed that it is arranged somewhat like a fan, the centre of which is at some depth and hidden from view. From this centre the columns radiate in regular fan-like form, until at last they reach the present surface of the land, being covered by only about two feet of surface soil.

The section at Ladeddie Hill is somewhat similar to that at the remarkable rocks about five miles due east, known as the "Rock and Spindle," on the coast near St Andrews, described so long ago as 1813 by the Rev. Prof. Fleming,* then minister of Flisk, and afterwards by Lyell in his "Manual."† This singular rock, says Lyell, "consists of a pinnacle of tuff which may be compared to a distaff, and near the base is a mass of columnar greenstone, in which the pillars radiate from a centre and appear at a distance like the spokes of a wheel." "I conceive," he says, "this mass to be the extremity of a string or vein of greenstone which penetrated the tuff. The prisms point in every direction, because they were surrounded on all sides by cooling surfaces, to which they always arrange themselves at right angles." Lyell explains this arrangement of columnar igneous rock by reference to the lava of La Coupe d'Ayzac in one of the valleys of the Vivarais, a mountainous district in the south of France.‡ There the lava consists of the following section in descending order:—1st, Scoriaceous lava as the uppermost layer; 2d, lava with irregular prisms as the next layer; and 3d, lava with regular columns which are inclined always at a right angle to the cooling surface of gneiss, upon which this, the lowest layer of lava, rests.

Now, I think by comparing the sections given at the "Rock and Spindle," near St Andrews, and at the Coupe d'Ayzac, we have the history of the formation of the Ladeddie Hill section of columnar basalt, with its attendant amorphous basalt and bed of volcanic ash. Let us next look at some of the other igneous phenomena of the district around Ladeddie Hill.

All this district of Fife bears evidence of violent volcanic action during an ancient geological period, probably the Lower Carboniferous. The many picturesque crags of trap rock which enliven the scenery of this part of Fife are vestiges of the ancient lava-flows. Rising from amid the classic sandstones of Dura Den, belonging to the uppermost Old Red or lowest Carboniferous strata, the igneous rocks here produce striking eminences, such as Blebo Craigs (400 feet), Clatto Hill (547 feet), &c. At the quarry of Craiglumphart, near Blebo Mains, the greenstone

* "Memoirs of Wernerian Society," vol. ii. p. 145.
† Fifth Edition (1855), p. 562.
‡ Op. last cited, p. 488.

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which forms the common trap rock of the district has been quarried for road metal, until recently the more durable basalt of Ladeddie Hill came to be discovered and preferred. I exhibit specimens of both these rocks, from Craiglumphart and Ladeddie respectively. The discovery of the superior excellence of the basalt seems to have been made quite recently; and the rapidity with which the quarry at Ladeddie is being worked out may be judged when I mention that within a few months a space of about twenty yards by ten, formerly entirely occupied by columnar basalt, has been completely removed. But were our own Salisbury Crags not once attacked by the quarrier in the same way until public opinion rebelled and saved them from demolition? Hugo Arnot, in his well-known "History of Edinburgh," published in 1779, speaks of the rocks of Salisbury Crags "affording an inexhaustible supply of hard stone for paving the streets; and of these stones considerable quantities are sent for paving the streets of London." (P. 310.) We are probably now devoutly thankful that a stop was put to this Vandalism, and that these historical rocks which formed the chosen battle-ground of the Huttonians and Wernerians,* and which enabled the former to establish some of the first principles of geology, were spared the indignity of being completely quarried away "for paving the streets of London."

In a paper which I read before this Society in 1872 † I mentioned that "the coast-line from Aberlady to Dunbar presents a singular instance of volcanic action," and I described the volcanic rocks more particularly of the North Berwick coast. All that coast furnishes splendid examples of volcanic eruptions and lava-flows on a vast scale. So, crossing to Fife, we find the same remarkable igneous phenomena stretching along the coast from North Queensferry to Kirkcaldy, and from Largo to St Monans. Yet instances of columnar basalt are comparatively rare, and so beautiful an example as that at Ladeddie Hill is most uncommon. It was for this reason that I have called attention to it in this paper before its last vestiges are removed by the pick and hammer of the quarryman; for you will agree with me in thinking that one of the chief uses of a Geological Society such as ours is to record the existence of geological phenomena of interest occurring in the district embraced by our observations.

Five miles in a straight line south from the section of Ladeddie Hill stands Largo Law, 900 feet in height. Dr Archibald Geikie, our former President, in his recently published admir-

* Charles Maclaren describes the exact place of conflict in his "Geology of Fife and the Lothians," second edition (dedicated to our Society), p. 58 (1866).
† "Transactions," vol. ii. p. 177.

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able "Text Book of Geology," figures (p. 559) a section of Largo Law, wherein it is represented as consisting of two eminences, the centre of each of which is composed of basalt, which broke through the lower carboniferous strata. Heaped around these basalt "necks" of the two ancient volcanoes lies, in conical form, the tuff or fragmentary volcanic materials ejected by the volcanoes; whilst veins of basalt penetrate the tuff, one forming a crag on the eastern slope of Largo Law. A large area surrounding Largo Law is composed of volcanic tuff or ash, just as a large area surrounding North Berwick Law is composed of the same materials. At a greater distance round Largo Law we find evidence of extensive ancient lava-flows, some now consisting of basalt, some of greenstone. Ladeddie Hill is only one of the eminences attesting the volcanic energy of this period, and it lies at the north-eastern extremity of basaltic hills between Largo Law and the valley of the Eden. Between Laddedie Hill and Largo Law occurs the basaltic eminence known as Dunikier Law, whilst to the east of Largo Law we find a broken line of igneous rocks stretching to St Andrew's Bay, the famous "Rock and Spindle," already described, being one. On the whole, a volcanic area of some thirty miles in circumference surrounds Largo Law, where probably the chief volcanic vents were situated, although minor volcanic vents also occurred.

As to the nature of these ancient volcanoes, whether they were subaerial or submarine, or first the latter and then the former, it is interesting to speculate, but must be difficult to decide. On the one hand, we find that occasionally the ejected blocks or bombs fell with such force upon sedimentary material as to lead one to suppose that there was no water to break the force of their fall. An instance of this occurs near Pettycur, Burntisland, and is figured in Dr Geikie's "Text Book" (p. 566). "Here," says Dr Geikie, "such ejected blocks or bombs are found among fine shales and other strata, the lamination of which is bent down round them in such a way as to show that the stones fell with considerable force into the still soft and yielding silt or clay."

On the other hand, we have also evidence of periodic marine invasions after periodic eruptions. Thus, as I pointed out in my paper on the North Berwick coast, intercalated layers of sandstone are found within the ash on the beach at North Berwick, and I remarked that "it is evident that after each volcanic outbreak the sea has flowed over the deposits of ash, as attested by the intercalated layers of sandstone." *

Perhaps Professor Judd's theory of the formation of Arthur's Seat may throw light upon the history of our ancient volcanoes.

* Paper cited *supra*, p. 179.

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He says: * "At about the middle of the Calciferous Sandstone period (Lower Carboniferous), a great fissure opened in the district, and began to emit, at several points along its course, discharges of vapour carrying with them fragments of rock, cinders, and ashes, alternating with the outflow of currents of lava." He proceeds, "That the earlier eruptions of this locality took place in shallow water appears certain from the nature of the fossils found in the stratified tuffs at St Anthony's Chapel." He concludes, "Eventually, by gradual elevation, this submarine volcano became a subaerial one, as is shown by the characters of the agglomerates composing the higher and later portions of its mass." Prof. Judd cites Graham's Isle and other modern volcanoes as illustrating the history of the old carboniferous volcano of Arthur's Seat. Now, our former President, Charles Maclaren, in his classic "Geology of Fife and the Lothians," also mentions Graham's Isle as illustrating Arthur's Seat. He says (p. 55) that "this island was the product of a submarine volcano which showered out fragments till it raised a cone 800 feet in height above the bottom of the Mediterranean Sea," where it appeared in 1831. Maclaren shows, by means of a diagram, the three successive stages of Graham's Isle, viz:—1st, the island as it existed when the cone rose one or two hundred feet above the sea, and which, he considers, illustrates the formation of the celebrated *Puys* or volcanic hills of Auvergne; 2d, the island when marine denudation had swept away the cone; and 3d, the island when the marine denudation had left only a boss of basalt standing above the volcanic ash, as in the case of Arthur's Seat, the summit of which is 822 feet above the sea.

In his recently published Life and Letters (vol. ii. p. 205, 1881), we find Sir Charles Lyell writing to Leonard Horner on 5th September 1855, that he had visited Edinburgh, and made geological excursions with Hugh Miller, Charles Maclaren, and Professor Fleming. Referring to his meeting with Professor Fleming, Lyell says:—"I had two good talks with him, and a walk over the Calton Hill and over the coast of Fife from Kinghorn to Kirkcaldy. I view the Edinburgh and Fife rocks with very different eyes, now, since Madeira and the Canaries" (which Lyell had visited during the preceding year). "They are in part intrusive, in part *sub-aerial* in my opinion, in part estuarian, like the associated Burdie-house coal measures, which last are the lower portion of the coal series."

In conclusion, I may refer to an interesting woodcut occurring at p. 257 of Dr Geikie's "Text Book," as showing, in Dr Geikie's opinion, that what he styles "old fissure or massive eruptions" give rise to masses of columnar basalt of a nature similar in

* "Q. J. G. S.," May 1875, p. 145.

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appearance to that I have described at Ladeddie Hill, only without the accompaniment of volcanic ash, which brings Ladeddie Hill under the head of ordinary volcanic phenomena. Dr Geikie's sketch is of the great Basalt Plain of the Snake River, Idaho, in western North America, which he visited in 1879. He says he rode for many miles along the Snake River, and "found the surface to be everywhere marked with low hummocks or ridges of bare black basalt, the surface of which exhibited a reticulated pavement of the ends of columns." He adds, "There are no visible cones whence this enormous flood of basalt could have flowed. It probably escaped from many fissures still concealed under the sheets which issued from them." He concludes, "It arose from what may have been on the whole a continuous, though locally intermittent welling-out of lava from many fissures extending over a wide tract of Western America during a late Tertiary period, if indeed the eruptions did not partly come within the time of the human occupation of the continent."

I have now discussed all the details which seemed to me to be of interest in connection with the phenomena at Ladeddie Hill. My only regret is that the beautiful rock-structure exhibited there will soon be placed, by man's destroying hand, beyond the reach of geological chronicle or criticism.

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XIV.—*Note on Boulders exposed at the New Cemetery, Easter Road.* By ANDREW TAYLOR, F.C.S., *Associate.*

(Read 19th April 1883.)

THE Easter Road Cemetery appears to rest on that series of sands, gravels, and clays lying betwixt the Calton Hill and the sea-shore, which are amongst the most unique of the surface formations of the Edinburgh district. It stands generally on the 100 feet contour line. The nearest sites where the older rocks appear at the surface is at the Calton Hill and at Lochend, in its immediate vicinity. During the drainage operations, gravel, clay, and sand were only come on.

Through the kindness of H. Belfrage, Esq., C.E., of Messrs Carfrae & Belfrage, C.E., my attention was directed to some curious boulders exhibited during the progress of the works. I also received a loan of the contractor's plans and sections. As the latter coincide with the walks now permanently laid out, the visitor can perfectly understand the striking phenomena thus shown in this limited area of about eleven acres without pictorial illustrations.

The principal section runs along the course of the main walk, by the entrance gate, running parallel to the Easter Road, but embracing a semicircular sweep, so as to join the centre walk at both of its extremities. The principal bed of boulders was found nearly at the northern extremity, and extending midway down the principal foot walk. The section shows about 121 feet of clay, with boulders, having an average thickness of 5 feet; above this a small tongue of gravel containing boulders, followed by the superficial soil. Generally the succession was only clay and sand, the clay suddenly coming to a point and being followed by displays of sand alone. The clay stratum just described proceeds but a short distance towards the centre of the cemetery. In sections through the lines of side walks, it thins off into the sand at distances varying from 87 to 139 feet. The boulders obtained were, in most cases, 1 to 1½ foot by half a foot, and in two instances noted, scratched along their centres. The mineralogical characteristics of the Salisbury Craigs greenstones and sandstones, predominated amongst them.

Another bed of clay was discovered along the upper walk running parallel to the railway. At the point now marked by a large circular garden patch, a few boulders were come on; but

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generally the clay extended to the end of the walk almost in a pure state, extending inwards to a point on a branch walk down the cemetery, now marked by a smaller circle, about 135 feet from the south-eastern boundary wall. The clay which along this line is 7½ feet thick, in a vertical section of 9½ feet, suddenly thins off into sand, which continues till the patch of clay and boulders just described is reached.

Another large section of clay, similar in constitution to the above, appears to bend away from the entrance gate in the direction of the Easter Road. As the boring operations did not extend outside the cemetery, its western limits are unknown.

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XV.—*The Fossiliferous Rocks of Borrowstounness Coal-field.* By H. M. CADELL, B.Sc., of H.M. Geological Survey.

(Read 19th April 1883.)

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I. Palæontological Characters of the Lower Rocks.
II. Characters of the Coal-bearing Strata of the lower portion of Bo'ness Coal-field :—1. Smithy Coal and Fossiliferous Shale above it. 2. Section of Strata above Main Coal in No. 6 Pit, Bridgeness. 3. Roof of Easter Main Coal. 4. Six Feet Coal. 5. Lower Ironstone Seam. 6. Formation of Common Coal. 7. Formation of Parrot or Cannel Coal. 8. Formation and Origin of Clay Ironstone.
III. Appendix :—A. Section of Strata in No. 18 Pit, Kinneil. B. Fossil Plants of Bo'ness, by R. Kidston. C. Mollusca, John Young, F.G.S. D. Fishes.

I. LOWER ROCKS.

THE lower marine (the so-called "mountain") limestone usually taken as the inferior limit of the Scottish Carboniferous Limestone series is nowhere very distinctly seen on the Linlithgowshire coast, but the numerous blocks scattered about on the beach may be taken as an indication that its outcrop is about a mile and a quarter to the west of Blackness Castle, under the drift which at that place prevents the rock from being seen.* The thin argillaceous limestone or "cementstone" which crops on the foreshore a short distance farther east, appears to be totally unfossiliferous, and has no resemblance to the great encrinal limestone of Charleston on the opposite shore of the Firth. The neighbouring rocks are chiefly shales and thin calcareous sandstones with fragmentary plant remains such as calamite stems, leaves, and scales of Lepidodendron, &c. The shales often contain beds of clay ironstone nodules, in some of which are to be found marine shells associated with small pieces of Calamites and other land plants. *Orthoceras undatum* (Flem.) is the only fossil which it has been my fortune to find in these nodules in a perfect state. The next rocks in the ascending series are sandstones, with ferruginous limestone bands and beds of shale. Immediately below the tuff at Carriden is a bed of black shale on which rests a coal seam a few inches in thickness. It is in turn overlaid by a bed of hard sandstone whose surface is covered with beautiful sharply-cut impressions of *Spirophyton cauda galli*, but, so far as I am aware, no true organic remains are to be found in the rock itself. Above the

* The sketch map and sections accompanying the "Notice of the Bo'ness Volcanic Rocks," "Trans. G. S. E.," iii. p. 305, *et seq.*, will serve to show positions of localities and pits below referred to.

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tuff comes a series of laminated and bedded sandstones and a bed of limestone with a few crinoids, about a foot in thickness, to be seen in Carriden Glen above the waterfall, and also in the adjoining old quarry at Burnfoot. Its position is indicated on the General Section attached to the author's former paper on the Volcanic Rocks of the district ("Trans. Geol. Soc. Edin.," vol. iii. p. 312).

II. Coal-bearing Strata.

Having thus briefly glanced over the lower series of rocks to the east of Bridgeness, let us now call the miner to our aid, go with him down one of the pits, and, beginning at the lowest valuable seam, work our way upwards through the overlying rocks, and the coals and ironstones associated with them.

1. The "smithy coal," with a thickness of about 3 feet, has a roof of dark blue shale rich in organic remains. These are chiefly shells and fragments of Ganoids and Placoids. Of the Brachiopods, the well-known *Lingula squamiformis* and the minute *L. mytiloides* characterise the portion of the shale immediately over the coal. *Productus cora, P. scabriculus, P. semireticulatus* var. *Martini*, and *Discina nitida* are less abundant, and occur higher up in the bed. By far the commonest species of the Pelecypods is *Aviculopecten ornatus*, of which there are three varieties—tumid, elongated, and distorted. *Edmondia sulcata* is also rather common. Other forms are—*Leptodomus costellatus, Myacites sulcatus, Modiola lithodomoides, M. lingualis, Schizodus* (*Axinus*) *carbonarius, S. deltoideus, Myalina Verneuilii.* The Gasteropods are but poorly represented in the two species of *Bellerophon, B. striatus*, and *B. Urii.* The Cephalopods occur in broken pieces of Orthoceras, of which I have only found one large enough to be identified as *O. attenuatum.* I agree with Mr John Young, F.G.S., of the Hunterian Museum, Glasgow, to whom my warmest thanks are due for identifying the Bo'ness mollusca, that further search in this bed would yield many other fossils; but alas for the fossil-hunter! the strata above the smithy coal are pierced only on those occasions, as few and far between as transits of Venus, when a new shaft happens to be sunk through them.

I have also to thank Dr Traquair, F.R.S., for looking over the fish remains from the district, but their fragmentary state has generally rendered identification of species an impossible task. Spines of *Acanthodes*, teeth of *Pœcilodus* and *Rhizodus Hibberti* are moderately common. I have found one well-preserved spine of *Tristychius arcuatus*, one of *Ctenacanthus*, and a beautiful little longitudinally striated spine about an inch in length of an undescribed species.

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The fossils just mentioned are all from No. 18 Pit, Kinneil Colliery, which has recently been deepened to reach the smithy coal. The sump of No. 6 Pit, Grange Colliery, at Bridgeness, is sunk into a higher bed of shale a couple of fathoms below the main coal. This shale is harder and more arenaceous than that just mentioned, and contains small micaceous flakes. It has many beautiful black enamel-like diamond-shaped plates and small brown teeth of *Megalichthys*, as well as teeth and scales of *Rhizodus*, *Eurynotus*, *Rhizodopsis*, and *Deltoptychius*, along with shells of *Lingula squamiformis* in a good state of preservation.

2. The beds above the main coal as passed through in sinking No. 6 Pit are (in descending order) as follows:—

	Ft.	Ins.	
Surface Clays, Sands, Gravels, &c., to Rock	103	3	Described in detail, "Trans. Geol. Soc. Ed.," IV., p. 12, *et seq.*
Sandstone, Blaes, and Fakes	9	10	Ripple marked, few fossils.
Blaes (non-bituminous shale)	5	11	With Ironstone nodules.
Ironstone band . .	0	3	Not carefully examined, but apparently almost unfossiliferous.
Blaes	1	1	
Ironstone band . .	0	1	
Dark gray Sandstone	3	8	
Sandstone, white . .	2	10	
Blaes	17	7	
Ironstone band . .	0	3	
White "calmy" Blaes	0	8	
Dark hard Blaes . .	0	6	
White clay bed "Calmstone," passing down into	0	9	Alluded to "Trans. G.S.E.," iii. 306. Contains many very beautiful but fragile plants, *Sphenopteris Dicksonioides*, *S.* ? *elegans*, *Sphenophyllum*, *Asterophyllites*, *Lepidophloios*, *Calamites*.
Whinstone (Dolerite)	8	0	White top and bottom, green in middle, highly amygdaloidal on top. Contemporaneous lava stream.
White Sandstone . .	38	3	Very much indurated on top, plant remains and *Stigmaria* towards base.
Dark Sandstone . .	2	7	
Fakes	2	5	
Blaes	0	7	
COAL, "Red Coal" .	3	0	
Carry forward	201	6	

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	Ft.	Ins.	
Brought forward	201	6	
Light Fireclay and dark sandy Blaes	2	0	This is evidently an ancient soil, thoroughly unstratified and full of vegetable remains, with some *Stigmaria* rootlets.
White Sandstone	11	10	Dark at base, and having lower surface covered with matted ivy-like impressions (roots ?).
Blaes	6	2	
Ironstone band	0	4	
Coarse Cannel Coal	0	5	
Sandy Blaes	8	4	
Ironstone band	0	2	With plant impressions.
COAL, "Fireclay Coal"	1	2	
Fireclay (under clay)	5	4	With *Stigmaria* and a few ironstone nodules. Old soil.
Coal	0	2	
Soft dark Sandstone	3	0	
Fakey Blaes	12	0	
Dark hard Sandstone	6	1	With good impressions of *Lepidodendron* and *Lepidostrobus*.
Blaes	2	2	
Ironstone	1	5	Impure finely stratified clay ironstone, deposited in perfectly tranquil water.
Blaes and Sandstone	1	6	Bituminous, sometimes containing fish remains.
Black Shale	3	0	
Ironstone band	0	2	
Sandstone	5	4	Hard on top, but very open and porous at base, with pebbles of quartz ¼ in. diam. *Stigmaria* rootlets on top, black vegetable impressions below.
Harder bed of Sandstone	1	0	Ripple marked top and bottom. No fossils.
Fakes	1	0	
Blaes and Fakes	5	6	With crushed shells of *Edmondia rudis*. Lower part full of beautiful impressions of *Lepidodendron Veltheimianum L. Rhodeanum*, *Sigillaria*, a *Sphenopteris*, *Calamites*, &c.
Fakes and Sandstone beds	5	6	
Soft Fakes	2	0	
Blaes	7	3	
Ironstone band, "Kennel"	1	3	
Carry forward	295	7	

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	Ft.	Ins.	
Brought forward	295	7	
COAL, "Craw Coal"	0	9	"Lower Ironstone and Parrot" seam, here 2 ft. 8 in. in thickness. (Described below.)
Clay, with Ironstone nodules	0	3	
COAL, "Parrot" or Cannel Coal . .	0	8	
Blackband Ironstone.	0	3	
Light Fireclay, "Maggie"	0	2	
Ironstone band . .	0	4	
Light soft Shale, "Holing"	0	3	
Sandy Blaes . . .	5	2	With *Lepidostrobus variabilis.*
Coal	0	5	
Sandy Blaes . . .	1	4	
Coarse Sandstone. .	3	6	
COAL . . . 2 9 Dark Sandstone band . . . . 1 3 **COAL** . . . 1 5 Dauch . . . 0 4 **COAL** . . . 0 4	6	1	Full of *Stigmaria* rootlets. The "Six feet coal."
Dark Shaley Sandstone	2	8	This arenaceous fireclay is full of beautiful impressions of *Stigmaria ficoides* and *S. stellata, Bornia radiata, Lepidodendron.*
Hard Fakes . . .	8	5	
Blaes.	2	11	
Ironstone	0	3	
Coal (Cannel and common) . . .	1	2	
Dark Sandstone . .	3	3	With *Lepidostrobus.*
Coal (Cannel and common) . . .	1	2	
Dark Sandstone . .	3	2	With *Stigmaria.* Old soil.
COAL, Easter Main Coal	3	0	
Dark Freestone . .	3	8	Old soil, with *Stigmaria* and *Lepidodendron.* Stem 18 in. diam., rises 8 inches up through coal.
Fakes and Sandstone	8	7	
Depth	353	0	

Blaes in sump with fish remains, &c., already described.

3. The roof of the Easter Main Coal is tolerably rich in plant remains in the pits to the west of Bridgeness. Lepidodendron and Calamite stems are tolerably abundant, and occasionally a Sphenopteris or fragment of Asterophyllites is disclosed. I have in one case found a small piece of what

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appears to be coniferous wood in this shale, similar in appearance to that occurring in the tuff at St Magdalens, Linlithgow, and referred to in the notice of that volcanic rock (*loc. cit*, p. 314).

4. The six feet coal rests on a bed of shale full of plant remains. Among these may be noted the curious *Stigmaria stellata*, whose flat, star-besprent impressions are sometimes pretty large, reaching a breadth of about 9 inches. There are also many good specimens of the sigillaroid plant, with rows of round scars formerly called Ulodendron, as well as what appear to be badly preserved seed cases of Trigonocarpon-like forms. The roof of this seam is often pierced by tree stumps, which are attached to stems passing a foot or two upwards into the shale. These are often prolonged downwards into the middle of the coal, where they appear as great rounded or knotted ironstone balls, and injure the quality of the seam, which used partly for this reason to be known as the "foul coal."

5. The lower ironstone and parrot seam comes on a few feet above the six feet coal, and is one of the most interesting of the groups of strata we have to notice. Its most important and persistent member is the parrot or cannel coal, which has generally a thickness of over a foot, and is found in all the pits to the east and south of Bo'ness. It is perfectly homogeneous in texture, has a brown streak and flat conchoidal fracture, and sp. gr. = 1·249 . . . 1·272. It contains fixed carbon 54·54, ash 5·28, volatile constituents 40·18. So far as I am aware the only fossils in the coal itself are *Stigmaria* roots. These are of three kinds:—1st, Black resin-lustrous, in general very thin impressions, always in plane of coal, covered with shallow eye-like tubercular pits, edges fringed by dumpy flame-shaped rootlets, seldom exceeding an inch in length. The main root has generally a breadth of from 2 to 6 inches. 2nd, The ordinary *Stigmaria ficoides*, with sword-shaped, elongated rootlets, often a few inches long, also in plane of coal, but not so thin or so broad as the first variety. This fossil is almost invariably converted into pyrites or marcasite, which decomposes very rapidly on exposure to the atmosphere, covering the coal with a white crystalline efflorescence of ferrous sulphate. 3rd, Wrist-thick *Stigmaria ficoides* roots, with the usual tubercled surface, running through the coal in all directions, but generally at a considerable angle to the bedding plane. The roots are in this case filled up either by clay ironstone or indecomposable marcasite. In the first case no structure is preserved, and the ironstone, which has a tolerably uniform thickness and section, is traversed by the same dip and strike joints which divide the coal. In the second case the brass-yellow sulphide is often

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knotted and irregular, and is not cut by joints. When seen in cross section it shows a central homogeneous core, surrounded by a ring, with radial lines resembling a double elliptical arch, with large voussoirs.

The first of these varieties is by far the commonest, and indeed it is difficult to find a piece of coal quite free from the shining impressions. I have examined many hundreds of specimens, and do not remember having seen a single one in which the vegetable was replaced by mineral matter. The third variety is rarer, and occurs in greater abundance at some places than at others. The fossils are easily separated from the coal, and do not, therefore, injure its quality much.

The parrot is usually found resting on a bed of amorphous coarse blackband ironstone, 3 to 5 inches thick, whose *upper* surface is covered with ordinary *Stigmaria ficoides* roots. The only other recognisable fossils from this ironstone appear to be teeth of *Rhizodus Hibberti*, which are usually beautifully preserved, and often covered with a thin film of pyrites. The teeth are found principally on the *lower* surface of the ironstone, which has no important vegetable impressions.

In the pits along the shore, from Bridgeness to Bo'ness, the parrot is overlaid by a light coloured clay, with knotted ironstone nodules (so called "curly ironstone"), above which comes a seam of common coal, averaging about a foot in thickness. The roof of this seam at Bridgeness, like that of the six feet coal, contains a great many tree stumps. I went round the levels and working faces of the submarine workings to the west of Bridgeness Pier in the beginning of 1881, and counted 113 in a distance of about 400 yards. They ranged from 3 inches to 2 feet, and probably averaged 1 foot in diameter. The enveloping ring of bright cherry coal was about a quarter of an inch in average thickness, and showed the vertical slickenside-like striations commonly found in such cases. The majority of the stems appeared to be lying over towards the north. Many flattened stems and branches are seen in the roof of the coal. Most of them are Lepidodendra, but I found a very good piece of the bark of *Lepidophloios macrolepidotum* in the thin ironstone band which covers the coal worked in a mine at Grangepans, half-way between Bridgeness and Bo'ness.

The parrot and ironstone covered by this thin coal extend westwards nearly as far as Kinneil, and are worked from the Schoolyard Pit, in the middle of Bo'ness. The thickness remains pretty uniform in the submarine workings to the west of Bo'ness harbour. The section in this pit, kindly given me by the late Mr White, underground manager, Kinneil colliery, is:—

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	Inches.
Coal	3
Kennel Ironstone	5
Coal, "Craw Coal"	9
Light fireclay rib	2
Coal, Parrot Coal	16
Ironstone	3

Blaes or coal pavement.

In the Snab Pit (the most westerly shaft in the district) the ironstone and parrot are not to be found. A thin coal occurs 19½ feet above the six feet coal, which may be the craw coal; but it is evident the parrot coal itself has not been formed there at all. It disappears as we approach the trappean region to the south, not being found in a workable state on the north-west side of Bonnytoun Hill. To the east it has been worked to the outcrop in the neighbourhood of Carriden road, and there shows signs of thinning out. It continues northwards under the bed of the Firth, but is not found in the Preston Island section on the other side, so that it must have thinned out somewhere under the middle of the present sea-bed.

The section of the parrot and ironstone seam at No. 5 Pit, Bridgeness, about a quarter mile south-west of No. 6, is as follows:—

	Ft.	Ins.
Ironstone band, "Kennel"	0	4
Blaes	0	6
Coal, "Craw Coal"	1	2
Ironstone nodules, "Curly Ironstone"	0	3
Light Fireclay	0	3
Coal, Parrot	1	2
Blackband Ironstone	0	3

Traced southward the upper part of the seam undergoes an interesting change. The craw coal thins out and becomes replaced by a bed of brown clay ironstone. The section of the seam in the "Red Coal" Pit, situated nearly three-quarters of a mile south of Bridgeness, is:—

	Ft.	Ins.
Clay band, Kennel	1	2
Blaes, lower part bitumenous	2	2
Brown Ironstone clay band	1	0
Fireclay, with Ironstone nodules	0	2
Coal, Parrot Coal	0	9
Blackband Ironstone	0	3

The craw coal is here completely replaced by the brown ironstone, which has at some places a slightly greater thickness. It forms a lenticular deposit on the top of the parrot, extending from

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Carriden road westwards to the hamlet of Kinglass, and southwards from the Drum farm to the Roman road on the top of Bonnytoun Hill, thus covering an approximately circular area about a mile and a quarter in diameter. It has a brownish red or gray colour, and often weathers bright red, showing the presence of anhydrous ferric oxide, Fe_2O_3. Sometimes it is interbedded with laminæ of common coal, with bright lustre and parallelopipedal fracture, and has often beautiful, sharply cut impressions of *Lepidodendron, Lepidophloios, Lyginodendron,* &c. Fish remains, chiefly scales and coprolites, are common, and now and then the well-known tooth of *Rhizodus Hibberti* makes its appearance. The ironstone is at some places interstratified with or overlaid by a thin parrot coal, with the usual dull resinous lustre and conchoidal fracture, but quite distinct from the normal parrot seam below. It is named by the miners "wild parrot" or "pelt," and is poor in quality. This coal has evidently been formed as a regular deposit of minute vegetable particles. It is sometimes finely stratified, and at others shades off into the surrounding strata, and is thus quite different from the thin streaks of common coal whose boundary is always sharply defined against the ironstone in which it lies. This fine vegetable stratum contains a great many fish remains. Beautiful spines of *Gyracanthus formosus* are sometimes found in it. Whole carcases of *Acanthodes* and *Elonichthys,* and detached scales of *Gonatodus,* usually converted into blue vivianite, are found in plenty, but not in a sufficiently perfect state for specific identification.

The roof of the brown ironstone seam is generally a bituminous shale full of mussels. The species which occurs most abundantly has been named by Salter *Anthracoptera tumida,* and is described in Memoir to Sheet 31 of the Geological Survey Maps (1879). The so-called "kennel band" which covers this shale is a poor clay ironstone, amorphous and homogeneous in texture, and to the best of my knowledge utterly devoid of fossils. It is cut by dip and strike joints which are usually coated with white calcareous dendrites like ostrich feathers.

6. The foregoing data enable us to form some idea of the conditions under which this seam was formed. While making surveys of the workings in various collieries in other parts of the Lothians, Fife, and Ayrshire, I have had opportunities of noting the characters of the seams in these districts, and have come independently to the conclusion that we can account for the origin of many common coals by supposing them to be entirely made up of bark of lycopodiaceous trees. The wood has almost entirely rotted away, and is now represented by particles of the so-called "mother of coal," or black charcoal-like substance

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which soils the fingers, and which is only found in planes parallel to the surfaces of the seam. In some cases these little charcoal-like pieces are much more numerous than in others, but in all the common coals, I have seen, they are present. It is quite unusual to find carboniferous tree trunks with any of the interior of the stem left in the form of altered vegetable matter. All the bitumenous matter that remains to tell of the tree that once was there, is a cylinder of coal surrounded and filled up by inorganic materials. Having thus good reason to believe that the coals in question are made up chiefly of bark and not of wood we have next to ascertain how that bark got there. In many cases there is an old soil with Stigmaria roots below the seams, which shows that trees once grew where the coal now is. In these cases it seems probable that the seam had a terrestrial origin, and that the coal was formed by generations of trees growing up, in course of time dying, and then falling over, the wood rotting away and the bark remaining as a vegetable soil on which the younger vegetation grew. It is probable that this process continued on land very little elevated above sea-level, as nothing is more common than to find little bands of shale or sandstone in the middle of the seam, probably produced by a slight submergence below the muddy water. These beds are very frequently filled with Stigmaria roots, as, for example, the band of shaly sandstone above described as dividing the "six feet coal" at Bridgeness. After this state of affairs had obtained for a certain period, a change in climate may have taken place, causing the vegetation to die; or, what is more probable, a subsidence may have submerged the forest and covered it up with a sedimentary deposit. Where the subsidence was slight the trees might have remained above water till the internal wood was quite rotten, and then broken over and floated away, leaving the stumps sticking in the mud which gradually covered them, and filled up the cylindrical cavity left by the woody core. This has evidently been the mode of destruction of the forests which formed the six feet and craw coals. In the latter seam, the fact that most of the stumps slope towards the north may probably be due to the prevailing wind, or to a storm having blown the trees over towards that direction. In other cases the trees appear to have had almost no soil. There is usually, however, a thin, shaley, semi-bitumenous bed below the seam, or rather, forming a part of it, called by the miners "Holing" or "Dauch." This may have been the original soil, and the rest of the forest may have grown on this and on the vegetable soil produced by the decomposition of the plants which first covered it, and the soil may from time to time have been fertilised by small inundations which did not bring in enough sediment to form a bed in the coal.

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The subsequent alteration by pressure, heat, and chemical agencies would in time metamorphose the material into coal.

It was formerly contested that common coal must have been produced as a deposit of vegetable matter, but the extreme regularity of the seams which sometimes extend for miles without altering their thickness, and the other circumstances just noted, preclude this idea. The brown coal deposits of Oligocene (Lower Tertiary) age in Germany, some of which I have lately examined, are true vegetable deposits. They lie, as might be expected, in basins, and are very irregular in thickness. They are usually 2 to 6 metres thick, but sometimes rise to 14, 20, 30, or even, as at Zittau, 50 metres (= 164 feet) in thickness, and are often earthy and interstratified with bands of clay. Unlike carboniferous coal they are composed not of bark but of wood of different kinds, chiefly conifers (Taxites, Pinites, Sequoia, Cupressinoxylon), Palms (Palmacites, Sabal, Flabellaria), and Dicotyledons (Betula, Juglans, Quercus, Cinnamomum). The Lycopods of the carboniferous age had dwindled down by this time, and another class of timber of a more sturdy description had taken their place. In the Dorothea Mine, Clausthal, Harz, an ancient level was opened some years ago in which the timbering (pine) was converted by pressure, moisture, and warmth (from decomposing pyrites) into a substance in no way distinguishable from true brown coal. The level was driven some 400 years ago, so that the metamorphosis of the wood had taken place within that period, proving that brown coal can be formed within a comparatively short space of time. True coal probably took a much longer time to form than the brown coal, inasmuch as the bark of a tree has a much less bulk than the wood itself, and the metamorphosis and consequent diminution in volume of common coal has been more complete.

7. Let us now turn from common coal to parrot or cannel coal, which is distinguished by its possessing a greater quantity of hydrocarbon, and by having different physical characters. It has a homogeneous texture, and is traversed by no joints parallel with the bedding plane, and is evidently not composed of laminæ of lycopodiaceous bark. It has apparently been once in the condition of a vegetable pulp analogous to a peat-moss, possibly a mass of floating vegetation, on which various varieties of plants flourished, as indicated by the roots already described as occurring in the coal.

The finely laminated "wild parrot" occurring with the ironstone is merely a deposit of fine vegetable particles laid down where the water became tranquil, such as may be seen in the bed of a stream flowing from a peat-moss after wet weather.

8. The parrot coal must have been deposited in water where

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fishes were swimming, and the blackband ironstone on which it rests was possibly originally a deposit of bog iron ore like that which accumulates in the shallow lakes of Sweden, Holland, and North Germany. This mineral is an impure hydrated peroxide of iron, $2Fe_2O_3 . H_2O$. It accumulates pretty rapidly, sometimes forming a bed of sufficient thickness to be profitably worked every fifty years. Ferric oxide deposited along with decomposing organic matter is reduced to ferrous oxide, which would combine with the organic acids due to the oxidation of organic matter and produce organic salts of iron, all of which by further oxidation would pass into ferrous carbonate. The reaction may be represented thus :—*

$$Fe_2O_3 - O = 2FeO.$$
$$2FeO + 2CO_2 = 2FeCO_3.$$

But whence the original ferric oxide? Some authors would fain have us believe it is from volcanic sublimations and so forth. Where, I would ask them, do we find evidences of such volcanic sublimations as would supply iron for the immense deposits of the Carboniferous, Jurassic, and Cretaceous periods, which are in general far removed both in space and time from all traces of volcanic action? No, it seems to me that a much better explanation is that of Dr von Groddeck, who, in his capital *Erzlagerstättenlehre*, p. 297, says, "Der Ursprung der Eisenlösungen ist in den Eisenoxydulsilicaten verschiedenster Gesteine zu suchen, die mittelst kohlensauerem Wasser zersetzt wurden. Es bildete sich daber kohlensaures Eisenoxydul, welches durch überschüssige Kohlensäure in Lösung erhalten wurde." † It is my belief that the iron came from the same source as the particles of sand and clay which compose the carboniferous rocks themselves. During the Old Red Sandstone period there was possibly not enough carbonic acid in the water to dissolve the ferric oxide which was accordingly deposited as such, and imparted its characteristic color to the rocks of a great part of the series. During the carboniferous age, however, when life was more abundant both on land and in water, and an immense quantity of decomposing vegetation existed on all sides, there must have been a great development of carbonic acid, which would at once attack the particles of iron oxide, reduce them to ferrous carbonate, and carry them off in solution. When so dissolved they could not be precipitated as ferrous

* I have to thank Dr J. J. Dobbie, of Glasgow University, for information on this point.

† The origin of the iron solutions is to be sought for in the ferrous silicates of the most diverse rocks which were decomposed by carbonic acidulated water. The ferrous carbonate thus formed was retained in solution by excess of carbonic acid.

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carbonate until shut up in a particular area, where there was not enough carbonic acid to keep them in solution, and where the oxidising action of the air was prevented. I am inclined to agree with Bischof, however, that the iron may have been precipitated rather as ferric oxide in presence of atmospheric oxidation, than as ferrous carbonate where the atmospheric action was excluded, and thus reduced to ferrous carbonate according to the above-stated reaction.

The fossils found in the upper beds are noted in the Appendix, and are not sufficiently interesting to call for further notice here.

APPENDIX A.

SECTION OF STRATA in No. 18 Pit (Lothians), Kinneil Colliery,* situated at the east end of Newtown and adjoining Kinglass Farm (see Sections, *loc. cit.*, pp. 306, 312).

	Ft.	Ins.	
Surface	26	0	
Whinstone	23	0	
COAL	1	6	
Fireclay	0	6	
Whinstone	48	9	
Sandstone	2	8	
Blaes	1	4	
COAL	1	3	
Sandstone	40	0	
Blaes	0	9	
COAL	1	4	Wester Main Coal, thickness, 10 ft. 3 in.
Fireclay	1	0	
COAL	1	4	
"Calmstone"	1	0	
COAL	1	6	
Blaes	1	1	
COAL	3	0	
Fireclay	1	0	
Whinstone	60	6	
Blaes	0	5	
COAL, soft	3	11	"Wandering Coal," thickness, 8 ft. 5 in.
White "Calmstone"	1	3	
COAL, splint	3	3	
"Calmstone," hard white	5	2	
Whinstone, soft green	7	6	
Carry forward	239	0	

* Kindly supplied by Mr Jonathan Hyslop, Manager of the Kinneil Colliery.

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			Ft.	Ins.	
Brought forward			239	0	
Black Blaes			6	6	
Sandstone, white fakey			9	0	
Blaes			23	6	
Whinstone			9	0	
Blaes, black fakey			9	0	
Whinstone			59	0	
Marl, white			9	0	Probably decomposed whinstone.
Kennel, hard green			3	0	
Sandstone, hard white			4	0	
Fakes, hard gray			11	6	
Blaes			0	9	
Marl and Ironstone Balls			1	0	
COAL			2	6	Red Coal.
Dark gray Fakes			0	3	
White Sandstone			2	0	
Bands of Blaes and Sandstone			24	0	
Ironstone Balls			0	8	
COAL			1	4	Fireclay Coal.
Fireclay and Ironstone Balls			4	0	
Bands of Sandstone, Blaes, and Fakes			36	0	
Ironstone Balls, coarse			0	9	
Black shale			2	6	
Ironstone Balls, coarse			0	9	
Blaes and Fakes			6	0	
Hard Kennel			0	8	
Blaes and Fakes			12	4	
COAL, free			1	1	Craw Coal.
Fireclay			0	3	
COAL, parrot	1	0	1	6	Position of blackband ironstone.
Do. do. foul	0	6			
Fakes			7	6	
Blaes			1	0	
COAL, soft			0	7	Six feet Coal, thickness, 5 ft. 10 in.
Fakes			0	5	
COAL, soft			0	9	
Band of fireclay			1	0	
COAL, splint			1	0	
Marl			0	7	
COAL, soft, with rib			1	6	
Coarse fireclay			8	4	
Foul Coal			0	6	
Depth to pavement of six feet coal			504	0	

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	Ft.	Ins.	
Strata below 6 ft. coal	—		
Easter Main Coal	—		Section as found in bore at west end of cross-cut mine.
Hard Sandstone	4	6	
Blaes and Fakes	18	9	
COAL	0	5	
Sandstone	4	9	
Fakey Blaes	7	7	
Hard Sandstone	11	0	
Fakey Blaes	12	10	
Blaes (fossiliferous)	11	3	
COAL	3	1	Smithy Coal.

APPENDIX B.

LIST of FOSSIL PLANTS collected in the neighbourhood of Bo'ness, identified, with notes, by R. Kidston, Edinburgh.

ALGÆ.

Spirophyton cauda-galli, Vanux., sp.

Ficoides cauda-galli, Vanuxeur. Géo. Report of third District N. York Survey, p. 156, fig., pp. 166 and 177.

Spirophyton cauda-galli, Hall. Sixteenth Report on the Cabinet of Nat. Hist. of N. York, p. 79, fig. 1, 1863.

Loc.—Sandstone on shore below Carriden tuff.

FILICACEÆ.

Sphenopteris Linkii, Goepp., sp.

Glechenites Linkii, Goepp. Die fossil. Farnkräuter, p. 182, Pl. II., fig. 1.

Sph. Linkii, Sch. Traité de Paleon. Végét., Vol. I., p. 383.

Calymmotheca Linkii, Stur. Culm Flora, p. 267, Pl. XII., figs. 1-6.

Loc.—Maidenpark Quarry (in Sandstone above Index Limestone), Kinneil, Bo'ness.

Sphenopteris Dicksonioides, Goepp., sp.

Aspidites Dicksonioides, Goepp. Die Foss. Farrnk., p. 361, Pl. XXVIII.

Pecopteris Dicksonioides, Sch. Traité de Paleon. Végét., Vol. I., p. 521.

Calymmotheca Dicksionoides, Stur. Culm Flora, p. 248, Pl. XXXIII., figs. 1-5.

Loc.—"Calmstone," at top of whin, above Red Coal, No. 6 Pit, Grange, Bo'ness.

Sphenopteris (?) elegans, Brong. (not Sternb.)

Sph. elegans, Brong. Hist. d. Végét. Fos., p. 172, Tab. LIII. figs. 1, 2.

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Diplothinema elegans, Stur. Culm Flora, p. 236, Pl. XIII., fig. 5, Pl. XIV., figs. 1-6.

Note.—A number of separated pinnules probably belong to this species, but they are too fragmentary for a satisfactory determination.

Loc.—"Calmstone," at top of whin, above Red Coal, and shale above Ironstone, No. 6 Pit, Grange, and roof of E. Main Coal, No. 3 Pit, Grange, Bo'ness.

Sphenopteris, sp.

Note.—Too indistinct for determination, but different from any of the above mentioned species.

Loc.—Roof of E. Main coal, No. 3 Pit, Grange Colliery.

"*Cyclopteroid*" pinnule.

A small fragment from shore, east of Carriden, below Stacks Farm.

CALAMITEÆ.

Calamites, sp.

Note. — This specimen, from its much constricted nodes, appears to be an internal cast, and cannot be determined specifically.

Loc.—In white sandstone, four fathoms above ironstone seam, No. 6 Pit.

Bornia radiata, Brong., sp.

Calamites radiatus, Brong. Hist. d. Végét. Fos., p. 122, Tab. XXVI., figs. 1 and 2.

Bornia radiata, Sch. Traité de Paleon. Végét., Vol. I., p. 335.

Calamites transitionis, Goepp. Die Foss. Flora d. Uebergangs, Tab. III., IV., X., and XXIX.

Calamites laticostata, Eltinp. Fos. Flora d. Mahr-Schles. Dachsch, p. 12., Tab. III., fig. 1.

Calamites inornatus, Dawson. Devonian Plants, Pl. XVII., fig. 56, 1862.

Archæocalamites radiatus, Stur. Culm Flora, p. 74. (Gives several plates.)

Loc.—Sandstone, under pavement of Six Feet Coal, No. 6 Pit, Grange.

Sphenophyllum erosum, L. and H.

Sphenophyllum erosum, L. and H. Fossil Flora, Pl. XIII.

S. erosum, var saxifragæfolium, Coem. and Kickx. Monog. d. Sphenophyllum d'Europe, 1864.

Sphenophyllites saxifragæfolius, Germar. Verst. d. Steink. v. Wettin u. Lobejün, Fasc. II., Taf. VII., fig. 1.

Note.—This plant is represented by only part of a verticil leaves.

Loc.—Roof, Easter Main Coal, No. 3 Pit, Grange, Bo'ness.

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LYCOPODIACEÆ.

Lepidodendron Veltheimianum, Sternb.

Lep. Veltheimianum, Sternb. Flora d. Vorwelt, Pl. LIII., fig. 3.—Schimper. Traité de Paleon. Végét, Vol. II. p. 29.—Stur. Culm Flora, p. 392, Pl. XXXV., figs. 2 and 3; Pl. XXXVI., figs, 5, 9, 10; Pl. XXXVII., figs. 1-6; Pl. XXXVIII., XXXIX., fig. 3.

Loc.—Brown Ironstone, Bo'ness; roof of Easter Main Coal; and Blaes, twenty feet above Lower Ironstone, No. 6 Pit, Grange.

Lep. Rhodeanum, Rhode.

Rhode. Beitr. z. Pflanzenk. d. Vorwelt, Taf. I., fig. 1a.—Stur. Culm Flora, p. 283, Pl. XL., fig. 1; XLI., figs. 1-3.

Loc.—Shale twenty feet above Ironstone, No. 6 Pit, Grange.

Lepidophloios macrolepidotum, Goldenb.

Lep. macrolepidotum, Goldb. Flora Saræpont. Foss., p. 37, Tab. XIV., f. 25.

Loc.—Ironstone Ball above Craw Coal, No. 4 Mine, Grange, Bo'ness.

Sigillaria, sp.

Note.—This plant has been figured by Stur under the name of Lepidodendron Veltheimianum, Culm Flora, Pl. XXXIX., figs. 1 and 2.

Loc.—Silver Mine Quarry, Linlithgow; Blaes, twenty feet above Parrot Seam, No. 6 Pit, Grange Colliery, Bo'ness.

Stigmaria ficoides, Brong.

Loc.—Common in the district.

Stigmaria stellata.

Loc.—Pavement of Six Feet Coal, Grange Colliery, Bo'ness.

Lepidostrobus variabilis, L. and H. Common.

CONIFERÆ.

Coniferous Wood (carbonised).

Loc.—In Tuff, St Magdalene's Quarry, Linlithgow; also on roof of Main Coal, No. 3 Pit, Grange.

APPENDIX C.

FOSSIL MOLLUSCA, identified chiefly by John Young, F.G.S., Hunterian Museum, Glasgow University.

Note.—*Specimens* marked with an asterisk have not been found by author, but are given in the list of fossils in the Memoir to Sheet 31 of the Geological Survey Map of Bo'ness. *Localities* thus marked have yielded fossils to the Survey collectors alone.

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α. *Brachiopoda.*

Discina nitida, Phill.	Roof smithy coal.
Lingula mytiloides, Sow.	Roof smithy coal.
L. squamiformis, Phill.	*Roof splint coal.
Productus cora, D'Orb.	Roof smithy coal.
P. semireticulatus, var. Martini, Sow.	Roof smithy coal.
P. scabriculus, Mart.	Roof smithy coal.

β. *Pelecypoda.*

Anthracoptera carinata, Sow.	Sandstone above Red C., Bridgeness.	
A. tumida, Salter.	Roof of parrot, Grange and Kinneil Pits.	
Anthracosia acuta, Sow.	Locality unknown.	
Aviculopecten ornatus, Eth., jun.	Smithy coal roof.	
*A. (near planicostatus), M'Coy.	Do.	
Edmondia rudis, M'Coy.	Shale 20 feet above lower ironstone, No. 6 Pit, Grange.	
E. sulcata, Phill.	Smithy coal roof, No. 18 Pit.	
Leptodomus costellatus, M'Coy.	Do.	Do.
Modiola lingualis, Phill.	Do.	Do.
M. lithodomoides, Eth., jun.	Do.	Do.
Myacites sulcatus, Flem.	Do.	Do.
Myalina Verneuilii, M'Coy.	Do.	Do.
*Nucula, N. sp.? (near lævirostrum, Portl.)	Do.	Do.
*Pteronites, sp.	Do.	Do.
Schizodus (Axinus) carbonarius, Portl.	Do.	Do.
S. deltoideus, Phill.	Do.	Do.
*S. sp. (near S. centralis, M'Coy).	Do.	Do.
*Solenopsis, sp. (near S. minor, M'Coy).	Do.	Do.

γ. *Gasteropoda.*

Bellerophon striatus, Flem.	Do.	Do.
B. Urei, Flem.	Do.	Do.
*Murchisonia striatula, De Koninck.	Do.	Do.

δ. *Cephalopoda.*

Orthoceras attenuatum, Flem.	Do.	Do.
O. undatum, Flem.	Lower rocks, shore below Stacks farm.	

ε. *Echinodermata.*

*Archæocidaris? (teeth). Smithy coal roof.

ζ. *Annelida.*

*Spirorbis, sp. Upper ironstone.

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APPENDIX D.

FISHES.

Acanthodes, sp. (whole specimens and spines). Lower ironstone. Smithy coal roof.

*Cœlacanthus lepturus, Ag. (scales). Upper ironstone.

Ctenacanthus, sp. (brevis? Ag.) (spine). Smithy coal roof.

Deltoptychius, sp. (scales). Shale, 2 fms. below easter main coal, No. 6 Pit.

Elonichthys, sp. (whole specimens). Lower ironstone (brown stone).

Eurynotus, sp. (scales). *Upper ironstone. Lower ironstone. *Splint coal. Shale below main coal, No. 6 Pit.

*Fissodus Pattoni, Eth., jun. Roof of splint coal.

Gonatodus, sp. (scales). Lower ironstone (brown stone).

Gyracanthus formosus (spines). Do. Do.

*Hybodus? (spine). Smithy coal roof.

Megalichthys, sp. (scales and teeth). *Upper ironstone. *Splint coal. Shale below main coal, No. 6 pit.

Pœcilodus, sp. (teeth). *Splint coal roof. Smithy coal roof.

Rhizodopsis, sp. (scales, &c.) *Splint coal. *Upper ironstone. Shale below main coal.

Rhizodus Hibberti. *Splint coal. Smithy coal. Lower ironstone.

*Strepsodus sauroides (teeth). Smithy coal roof.

Tristychius arcuatus (spine). Do.

Spine (undescribed).

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XVI.—*The Asymptotic Nature of Natural Selection.* By R. T. Omond.

(Read 19th April 1883.)

I suppose all the members present understand what is meant by the term "asymptote" in mathematics. The best example of it is found in the case of the curve known as the "hyperbola," where two straight lines may be drawn such that the two branches of the curve continually approach but never touch them. The reason is that though the curve is continually approaching the lines, the rate of its approach is always getting slower, and it never reaches them. These lines are called the asymptotes of the curve, and the curve may be said to asymptotically approach them.

It has often struck me that in many branches of physical science an asymptotic law prevails. Take an example from our own science, geology. If we consider the case of a country acted on by the ordinary geological agencies—rains, rivers, frost, wind, etc.—it is usually allowed that if their action be continued without interruption for a sufficient length of time the country will be reduced to a nearly level plain, rising little, if at all, above the surrounding ocean. But the most extreme uniformatarian will not deny that the erosion will take place faster at first when the land is high and mountainous, and will get slower in proportion as the hills are worn away and the violence of the torrents decrease. Thus the longer the land is exposed to these ordinary geological agencies the less powerfully and rapidly do they act upon it. The process of erosion in such a case is therefore an asymptotic one, for, as the eroding power of these natural agents depends on the elevation and contour of the ground, their effect must continually lessen as the land wastes away. Any one examining the erosion of the country, and trying to estimate its rate, would very much underestimate the time required to complete it, if he chanced to make his examination near the beginning; while if he paid his visit when the erosion was far advanced he would correspondingly overestimate the time required to bring a mountainous country into such a condition as he would see. This point is very clearly brought out in Dr Arch. Geikie's recently published Text Book, where he says, after giving statistics of the denuding power of certain rivers, "It is of course obvious that as the level of the land is lowered the rate of subaerial denudation decreases, so that on the supposition that no subterranean movements took place to aid

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or retard the denudation, the last stages in the demolition of a continent must be enormously slower than during earlier periods." ("Text-Book of Geology," page 445.)

To take another instance. If we consider a lake that is being filled up by sand, gravel, &c., brought into it by streams, it is evident that as the lake grows smaller and shallower through this silting up process, less sediment falls to the bottom, and a larger proportion of the whole is carried away by the effluent stream. Of course this latter part of the sediment may, by increasing the scouring power of the river, lower the exit level, and thus drain the lake; but, nevertheless, the filling up part of the process is asymptotic, for, if not interfered with, it gets slower as it goes on, and would never be completed. These examples will suffice to show the manner in which this mathematical expression may be applied to natural phenomena. Many others will occur to any thinking geologist.

This principle appears no doubt a mere conceit or useless play upon words in the examples given above. It becomes, however, valuable as a test or as a clue when investigating that great theory of evolution called by Darwin, "Natural Selection." For the basis of this theory is that a species of animal or plant may improve—that is to say, may become better suited to its habitat; and that this improvement takes place by those individuals who have been born with slight variations tending to make them better suited to their habitat, having the best chance of surviving and of leaving offspring which will inherit and transmit the favourable variations. Now, it was long ago pointed out that though an individual may be a little better fitted for the battle of life than his fellows of the same species, yet this by no means ensures his survival, for the odds, to begin with, are very heavy against any one particular individual living to a mature age, owing to the great overproduction in each species. But this chance of survival is greater the less developed the species is—that is, the less they are in harmony with their surroundings. For if all the members of a species are very well suited to their habitat, very well furnished for the battle of life, then the extra advantages possessed by those individuals born with favourable developments count for little; while if the species be far from perfect, any slight advantages will give the favoured individual a heavy pull over his fellows, and greatly increase his chance of survival. Moreover, these so-called chance variations do not take place without a cause, and to carry out the theory consistently we must look for the cause in the surrounding circumstances; and here again it is evident that as the species gets more in harmony with its surroundings, the impelling force causing these variations will get weaker, the variations will get

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fewer or less marked, and the whole process of development slower.*

But natural selection is not only concerned with the growth and development of any single species, it takes account of the struggle for existence among the various species inhabiting a country. Darwin applies the same general laws here, merely putting the species in the place of the individual above, and therefore the ultimate result will be the same. Whatever local and temporary changes may take place, the general course of development of the inhabitants of a country must get slower as time goes on, and they become more nearly perfect. Darwin in his books on natural selection is rather trying to prove and elaborate the manner in which natural selection acts, than looking to the results which follow if natural selection be taken as a fundamental fact, and the course of development be considered as a whole. But let us now consider what this general result is, assuming in the meantime that natural selection has full and uninterrupted sway, and that no great climatic changes take place.

Put briefly, it is as follows. The development of the inhabitants of a country seems to depend, at first sight, mainly on the mutual action of the various races and individuals on each other; but in this action there is no supply to keep up the continuous development. Hence, though the immediate action of natural selection is a struggle betwixt different races and individuals, yet the start and source of power of development is in the external circumstances of the country in question, that is, using the word in its widest sense, in the climate. The power of the climate to cause (directly or indirectly) variations will get less and less as the inhabitants get better suited to it, and the rate of development must fall off. If these statements are correct the rate of evolution of the various inhabitants of a country will follow the same asymptotic law that the rate of denudation does. It will get slower as time goes on, just as the erosion of a country gets slower as its hills are worn away, and its mountain torrents turn into peaceable lowland rivers. Any small spurt that may take place in the development of one particular species or genus will be merely a temporary irregularity, akin to a sudden increase of erosion caused by a landslip or other local phenomenon.

All this is, however, on the assumption that the conditions under which the action is going on do not change—in the case

* If the Darwinian principle be pushed to its extremest range, in order that evolution may get a starting point, we are driven to speculate on the probability of the ultimate particles or molecules of the universe being not quite in harmony with *their* surroundings. But this is a matter that may be left to the chemical or physical investigator; it does not directly concern geology.

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of the land under erosion no upheavals or subsidences; in the case of the animals and plants no change in the conditions of life. But we find in every country signs of disturbance of level, of upheaval, of volcanic agencies altering the surface contours of the ground, and so giving this asymptotic process of erosion a fresh start. Similarly, if there is to be any great and continuous development of the inhabitants of a land, great, and, from the evolutionist's point of view, tolerably rapid changes in the climate of the land, that is, in the conditions of life, are necessary. In any one country these changes may be caused by local alterations of the positions of land and sea, of the great ocean currents, prevalent winds, &c.; but if we are to seek for a cause affecting the whole world we must look to some such great cosmical causes of change as Dr Croll brings forward in his book, "Climate and Time." He supposes from certain moderately well-authenticated data concerning the variations in the eccentricity of the earth's orbit that the climates of the northern and southern hemispheres will at times get into an unstable state, such that the changes induced by the precession of the equinoxes (that is, by changes in the direction of the earth's polar axis) will cause alternate warm and cold periods of sufficient intensity to give a temperate climate at the poles, or to bury the temperate zones in sheets of ice resembling those which at present surround the southern pole. The period of the precession of the equinoxes is about 20,000 years, and if his calculations are correct, we should have every now and then a period of some 200,000 years or more, in which the climate and conditions of life are completely altered every 10,000 years. The eccentricity is at present small, and is very slowly decreasing, thus we have no great difference between the climates of the northern and southern hemispheres; and indeed the climate of the whole earth may be called *temperate* compared with what it is when the eccentricity is large. During these times (large eccentricity) natural selection will work in a far more rapid and thorough manner than we see it doing at present. When a country that has been long covered with ice and snow becomes in the course of a few thousand years a land with a tropical or subtropical climate, it may easily be seen that animals and plants entering and living in it are exposed to rapidly varying conditions of life. They will develope rapidly, every favourable change having great value. And because of the rapid alternations of climate the asymptotic process of natural selection never gets into its slower stages,—before the first stages of rapid development are over the climate has altered, and evolution has to start from a new basis and under new conditions. This effect of climate, it is to be carefully observed, is not a *direct* one.

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The direct effects of change of climate on species are usually slight and transitory, a return to the original conditions obliterating all the results of the change. But in this case climate acts through natural selection, and the results have all the widely varying and lasting character that that process stamps on its subjects.

So powerful does this climatic action appear to some that we ourselves—the genus Homo—have been put down as a product of the last Glacial Epoch!

On the other hand, species that live under very uniform conditions of life do not develope rapidly. Thus we know that certain species of Singula have come down to us almost unchanged from Silurian times; they have probably lived all the time in water of a tolerably uniform character as regards temperature, &c.

Be this as it may, the fact which I wish to call the attention of the Society to is, that when we find any natural process going on, it is not enough, and it is not correct, to measure its present rate of progress, and then assume that it has proceeded uniformly since its commencement: we must first examine and see if the process, whatever it may be, has been uninterrupted, and then if it has, we must assume, not that it goes on uniformly, but that it goes on at a continually diminishing rate. There are, no doubt, exceptions to this rule, but when thought over, they will be found to be wonderfully few, and to consist mostly of cases where only a part of the whole process is considered, and the general scope and result not taken account of.

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XVII.—*Notes on the Cervus Megaceros* (Megaceros Hibernicus). By G. H. KINAHAN, M.R.I.A., &c., Geological Survey, Ireland.

(Read 19th April 1883.)

THE Irish elk, so called from the number found in Ireland, has been found in the Shandon Cove, near Dungarvan, County Waterford, associated with the remains of *Elephas Primigenius, Cervus tarandus*, &c., and in the Ballinmintra Cave near Cappagh, also in the County Waterford, associated with rude stone implements. Broken bones have been found in some of the crannogs or lake dwellings and in the luscas or artificial caves, County Donegal; while they are said to have been found in Esker gravel near Dunmore, County Galway.

The larger "finds," however, are in boggy flats, but in such places generally many more heads than skeletons occur, as if the heads had been drifted by water and harboured together in some sheltered place. This seems to have been the case at Ballybetagh, near Kilternan, County Dublin, where the heads of over 110 male deer have been found; often two, three, or more, close together, without any of the other bones. Similarly, in the flats adjoining the Shannon, the heads and some few bones will be found together, more often than whole skeletons. Furthermore, female heads are rarely recorded in such places: this, however, may be due to the hornless heads having been passed over, they being supposed to be "only horses' heads;" but, at the same time, if such accumulations are due to driftage, the horned head should drift much more easily than the hornless. Such accumulations, however, may be passed over, as the principal object of this paper is to draw attention to the "finds" where the elks evidently died and were buried. In the low bogs and flats of the County Limerick, skeletons are numerous but scattered about. This might be expected, as in the older time large tracts of that county must have been swamp, in which the deer may have become pounded; but in other places there are small patches of bog, in which many skeletons occur together. I know of such places in Clare, Kilkenny, Kildare, Carlow, Wexford, and elsewhere, but will only draw special attention to some of those in Carlow and Wexford. In the County Carlow, near Old Leighlin, three skeletons of male deer were found in a small boggy patch in the drift, the patch being roundish and scarcely more than 100 feet in diameter. The bog of Ask, a little N.E. of Gorey, County Wexford, is about half a mile long, and on an average 150 feet wide, and in the deepest portion a number of

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skeletons were found. The exact number I could not find out, or if any of them were females. But at Kilowen, a few miles to the N.E., there is a nearly round boggy patch, less than 200 feet in diameter, in a hollow in the marl, that was full of a friable black mixture of peaty stuff, clay, and sand, on about two feet of clay. The "Kilowen elk hole" was drained about thirty years ago, and the black stuff carted away, and the skeletons of nine deer found. About a fifth of the black stuff was left in the south portion of the hole, and during 1882, while sinking a water hole for cattle, a tenth skeleton was found, while it is probable there are more in the undisturbed portion. The man who removed the "black stuff" stated to me that nearly all the skeletons were in the clay under the "black stuff." The last found was, however, entirely in the "black stuff." It has been stated that human remains were also found here; this, however, I find is incorrect.* Captain Woddroofe, the owner of the place, states he remembers two or three hornless heads in the lot.

It appears to me there are unexplained peculiarities about these Irish finds. *First*, there is the old question, why should there be such a number of the elk found in Ireland, while other mammalia are comparatively rare? *Second*, why is it that in these small boggy patches such numbers of skeletons occur together? And *third*, why is it that female skeletons are scarce compared with the number of those of the males? In answer to the first and second, I have made suggestions in the "Geology of Ireland," chap. xvii., but those suggestions do not appear to me to be perfectly satisfactory; and in regard to the third, it is commonly answered, that the female skulls are ignored as valueless, or as only "old horses' heads." This I believe in part to be true, but not entirely so, as some years ago I wanted to possess a female skeleton, and although I had a keen man looking for one in the county Limerick, it was two years before he found it. Furthermore, in no place elsewhere, except Kilowen, County Wexford, could I get a statement positively made that hornless heads had been found in connection with skeletons.

It however has occurred to me that there ought to be sportsmen, students in natural history, who are acquainted with the "deer at home," that should, from observation of their habits, be able to throw some light on the subject. In regard to the *first*, it might be asked, when the moose and reindeer migrate in hard weather where do they go to? also, do they frequent islands in which at times they may be pounded by the ice breaking up early, thus causing many to die in a limited area? *Second*, where are such deer wont to feed in early spring?

* It would appear that the man who sold the old bones from this place mixed with them human bones he had stolen elsewhere.

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do they frequent small grassy, swampy places, in which they could be easily impounded? And *third*, do the males and females emigrate together? also, are the males the more numerous of the two? or rather, do more males than females die at certain periods of the year, as is the case with salmon?

It seems peculiar that the elk remains occur more frequently in the clay under the peat than in the peat. This is a subject I, a short time ago, specially enquired into, on account of my friend, the late Dr Leith Adams, denying they were ever found in peat. The results of my inquiries were, that although they are not found in peat as often as I imagined, yet sometimes they undoubtedly are in it above the clay.

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XVIII.—*On a Calcareous Deposit at Starleyburn, Fifeshire.* By JOHN HENDERSON, Councillor.

(Read 3rd May 1883.)

MOST people passing along the footpath that skirts the shore between Aberdour and Burntisland must have observed the pretty little waterfall formed by the Starleyburn stream falling over the rocks into the harbour of that name; and any ordinary observer might notice the rocks and weeds, over which the water falls, incrusted with a grayish, slimy-looking substance, which, if he took the trouble to examine, he would find to be a deposit of carbonate of lime. The Starleyburn, the stream to which I allude, has been long known in the district for its petrifying properties, as fragments of wood and other substances which have lain for some time within the reach of its spray have been found to be incrusted with lime.

On passing along the road on one or two occasions I have observed this deposit of lime on the rocks and weeds within reach of the stream, and also incrustations of considerable thickness on the rocks a long way out of the reach of the stream, but it was only lately, when passing along the shore on the west side of the little harbour of Starleyburn, that I was struck with the vast amount of limestone that has been deposited here from the burn and springs in the neighbourhood. Close on the west pier of the harbour the deposit has accumulated to a thickness of between 20 and 30 feet. Even within reach of the tide it stands up in an overhanging cliff, from which great masses have been detached and fallen upon the beach. One of these masses measures upwards of 30 feet long by 25 feet broad, and about 10 feet thick, containing upwards of 250 cubic yards of limestone, and must be between 300 and 400 tons in weight. Several other large blocks from 50 to 100 tons in weight lie in a confused heap, just as they appear to have fallen from the cliff. This deposit extends along the shore for about 150 yards. It commences at its western extremity as thin incrustations on the rocks, and an agglomerate of stones and gravel of the beach cemented together by the lime; it gradually becomes thicker until it reaches its greatest thickness at the west side of the harbour, where it overhangs the beach, and when the tide is in the sea rises several feet up the face of the deposit. And what is remarkable is, that the sea seems to have little effect in preventing the deposit of lime from going on, as the green algae, which grow several feet below the high water mark, are getting covered at the present time.

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The deposit as it appears along the shore is of varied character: in some places it shows fine lines of lamination, in other places it is a perfect botryoidal limestone, and here and there under the overhanging mass it hangs down as stalactites, but the great mass consists of what is termed tufa or travertin of a porous nature, due, I believe, to its being deposited on moss and weeds in a green state, which decay and leave small cavities in the lime deposit. Embedded in the mass are numbers of land-shells, such as *Helix nemoralis* and others, and even above the reach of the tide, marine shells, such as Littorina and Patella, are to be found embedded in it. The question naturally arises, from whence comes all this lime which has been, and is at present being, deposited along the shore at this place? A section of the older rocks upon which this new deposit lies may help to explain this. The older rocks on this part of the coast of Fife belong to the upper part of the calciferous sandstone series, and about the same horizon as the Burdie House limestone, and the supposed equivalent of this limestone is wrought in a long range of workings about a quarter of a mile inland from Starleyburn, and about 200 feet above this recent deposit. The beds along the shore are mostly sandstone, and they dip at a low angle inland, or to the north-west. The ground rises very steep from the shore, rising to a height of 150 feet in about 100 yards, and the ends of the sandstone beds crop out on the face of the hill, and springs ooze out here and there between the beds, incrusting the rocks and weeds with lime. At other places thick deposits of lime cover the rocks where there are no evidence of springs. On applying to Mr Taylor, on whose grounds a number of these springs exist, for liberty to examine these, he at once offered to take me through his place and show me the springs and the burn, and thus I had an opportunity of examining the whole of the hillside, and of seeing the deposit in process of formation. The origin of these springs so highly charged with carbonate of lime appears to me to be this, that the rain which falls inland finds its way through the rocks, and in passing through the bed of limestone which I have mentioned as being the equivalent of the Burdie House limestone, or some other bed or beds of limestone in the immediate neighbourhood, carries away a portion of the lime in solution. Possibly the water may be charged with carbonic acid, which allows it to hold a greater quantity of lime in solution than it would otherwise do. This water rising again to the surface at a lower level, parts with the carbonic acid and precipitates the lime on whatever it passes over; or it may be that the water when it comes to the open air evaporates, and the surplus lime is deposited. It is remarkable that the Starleyburn itself deposits a great deal of lime

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where it falls over the rocks, but higher up where the burn runs on comparatively level ground, I could observe no deposit of lime. The quantity of lime carried away by these springs must be very great when we consider the extent of this deposit, and know that it is a mere fraction of what the water is carrying in solution into the sea, and even the deposit itself is getting broken up and carried away by the action of the waves. It is quite possible that some great cavity may be forming in the limestone beds from which these springs derive their supply, something like the immense caves that occur in limestone districts in other parts of the world.

With regard to the rate at which this calcareous deposit may be forming, I can form no estimate. These recent calcareous deposits in other parts of the world seem to vary considerably. Sir Charles Lyell mentions one instance at San Vignone, in Tuscany, where ancient Roman tiles were found at a depth of 6 feet from the surface in travertin, which was still in process of formation. At another locality not many miles from San Vignone, where there were some hot springs, as much as 30 feet of travertin had been deposited in twenty years.

That the relative level of sea and land has not changed much during this deposit of travertin at Starleyburn may be inferred from the mixture of land and marine shells which are found throughout the largest masses.

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XIX.—*Excursion to Kinghorn.* Mr JOHN HENDERSON, *Leader.*

16*th June* 1883.

The party examined the fossiliferous limestones, shales, and sandstones of the carboniferous limestone series, along with contemporaneous and intrusive volcanic rocks.

Joint Excursion to Stirling with the Glasgow Geological Society. Led by the GLASGOW GEOLOGICAL SOCIETY.

23*d June* 1883.

Excursion to Dunbar. Mr JOHN HENDERSON, *Leader.*

30*th June* 1883.

The party examined the ashbeds and calciferous sandstones to the west, and the carboniferous limestones of Catscraig and Skateraw to the east of Dunbar.

Excursion to Inchkeith. Mr JOHN HENDERSON, *Leader.*

14*th July* 1883.

The party examined the sandstones, shales, limestones, and calciferous sandstones, with intrusive and interbedded volcanic rocks.

XX.—*Joint Meeting of Societies at Banff,* 3*d and* 4*th August* 1883.

(*From "Scotsman" of* 6*th August* 1883.)

Most of the strangers arrived in Banff on Friday, and on the afternoon of that day a meeting was held in the Banff Museum, the varied contents of which were shown to the visitors by Rev. Walter Grigor, Pitsligo, and Mr J. Horne, Geological Survey, Huntly. Half an hour later parties were made up, and the town, as well as objects of interest in its immediate vicinity, such as Duff House and the Castle, were visited, under the guidance of gentlemen qualified to describe them. Among the places thus seen were The Turrets, having associations with Byron's boyhood, and the old churchyard on which the chapel of the Carmelites is believed to have stood. In the evening a meeting was held in the Academy, under the presidency of Mr A.

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Ramsay, St Leonard's, at which nearly a dozen papers were read. These included "Folk Riddles," by Rev. Walter Grigor, Pitsligo; "Peer Men," by Mr James Linn, Geological Survey, President of the Keith Field Club; and "The Flora of Banff and Neighbourhood," by Rev. W. S. Bruce, Banff. Mr Fraser's paper was illustrated by excellent drawings, and Mr Linn showed specimens of "peer-men" in such variety as could be equalled in few collections. "The Antiquities of Banffshire" were succinctly described by Sheriff Scott Moncrieff, a considerable portion of the paper being devoted to objects of interest on the sea coast, along which the excursion on Saturday was projected. "Notes on the Flora and Fauna of the parish of Keig, in Aberdeenshire," were read by Rev. T. Bell, minister of the parish, who submitted lists, showing that there have been found in the locality 242 plants, 14 carices, and 34 grasses — in all, 290 — which gives a very fair proportion of flowering plants. There were also 10 species of ferns, 4 lycopods, 2 of equisetae, and 91 mosses, the list of the latter being, however, incomplete. Of the fauna there are 49 permanently resident birds, and 18 summer and 4 winter visitors. There are 15 species of butterflies, and 22 of spiders. Mr Fraser, in a paper on the stone circles of Strathnairn, stated that within the watershed of the strath of the river Nairn there were the remains or sites of 25 megalithic circles, and in its immediate neighbourhood, between it and the river Ness, there were the remains of eleven or twelve more circles. Mr Fraser described at some length the features of each circle.

After this meeting the members of the Banff Field Club entertained their visitors to supper in the Fife Arms Hotel, Mr Ramsay again presiding, and Sheriff Scott Moncrieff and the Rev. James Milne, King Edward, acting as croupiers. There were about a hundred present. Among the gentlemen who spoke were Sheriff Scott Moncrieff, Provost Black, Elgin; Provost Williamson, Banff; Mr Fraser, Inverness; Mr James Spence, secretary of the Banff Field Club; Sheriff Blair, Inverness; and Mr Ferguson of Kinmundy. The last named gentleman, in replying to the toast of "Kindred Societies," said it was careful local work that gave the chief value to societies of the kind represented at that gathering, and he was very glad to observe in the Banff Museum that its accommodation had been devoted not to collecting a great quantity of general articles—what the old lady called "bigotry and virtue"—but that the Field Club had really set themselves to work out the natural history and archæology connected with their district.

On Saturday upwards of a hundred ladies and gentlemen drove some distance along the coast eastward, and visited a

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number of interesting places. The party drove through St Brandon's Howe, where the old fair of St Brandon was held, and spent there a very instructive hour in the neighbourhood of the castles of the Boyne. The more ancient of these buildings crowned a rocky promontory called the Craig of the Boyne, midway on the coast between Banff and Portsoy, where a few crumbling pieces of masonry are yet pointed out; but the Castle of the Boyne, properly so called, a more recent though still very ancient building, is situated a short distance inland, its walls and towers being in a good state of preservation. Portsoy, famous for its quarries of serpentine, was next visited, and about midday the party reached the ruins of the Castle of Findlater, the vaults of which were explored, under the guidance of Mr James Spence, author of the "Ruined Castles of Banff." Cullen House, the seat of the Earl of Seafield, was also visited, and its stores of historical paintings admired. A business meeting was afterwards held to determine the place of meeting for next year, and after some conversation the chairmen and secretaries of the various societies were appointed a committee to arrange as to the locus of the next meeting—the conveners to be Mr Ramsay, president of the Banff Field Club, and Mr Wallace, secretary of the Inverness Field Club.

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APPENDIX.

PAPERS READ BEFORE THE EDINBURGH GEOLOGICAL SOCIETY DURING SESSION 1882-83.

16*th November* 1882 (49th Anniversary Meeting).—1. Inaugural Address by Ralph Richardson, W.S., F.R.S.E., *Vice-President.* Subject—"Agassiz and Glacial Geology."—2. Reports by the Secretary and Treasurer.

21*st December* 1882.—1. On Sections exposed in cutting the Suburban Railway at the Canal, near Meggetland, by John Henderson.—2. Notes on the Submergence of Scotland, by David Cameron, Daviot.

18*th January* 1883.—1. Additional Notes on the Geology of Enzie, by Thomas D. Wallace, F.S.A. Scot.—2. Structural Geology of the Northern Extremity of Glen-More-nan-Alban, by Thomas D. Wallace.—3. Additional Note on the Old Red Sandstone of Strathnairn, by T. D. Wallace.—4. Note on River Erosion in Switzerland, by R. T. Omond.—5. On the results of the Analyses of Diatomaceous Deposits from the Peat of Kinnord, Ordie, Drum, and Black Moss, Aberdeenshire, and from Grest, Lewes, by Ivison Macadam, F.C.S., F.I.C., Lecturer on Chemistry, *Honorary Secretary to the Society.*

15*th February* 1883.—1. Notes on the Raised Beaches of the Firth of Clyde, by William Ferguson, Esq. of Kinmundy, F.L.S., F.R.S.E., F.G.S., &c., *Vice-President.*—2. Suggestions on the Nomenclature of Rocks, by G. H. Kinahan, M.R.I.A., &c., *Associate.*

15*th March* 1883.—Notes on the Geology of Easter Ross, by W. Hamilton Bell.—2. Fossils of the first Gilmerton Limestone, by W. Tait Kinnear and W. Anderson.—3. Notes on the Mineral Albertite in the Shales of Strathpeffer, by William Morrison, Dingwall Academy, communicated by W. Hamilton Bell.

19*th April* 1883.—1. Notice of Columnar Basalt at Ladeddie Hill, near Pitscottie, Fife, by Ralph Richardson, W.S., F.R.S.E., *Vice-President.*—2. On Boulders exposed at the New Cemetery, Easter Road, by Andrew Taylor, F.C.S., *Associate.*—3. On Fossiliferous Rocks of the Borrowstounness Coalfield, by H. M. Cadell, B.Sc. Read by Mr Gibb.—4. On the Asymptotic nature of Natural

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Selection, by R. T. Omond.—5. On the Cervus Megaceros in Ireland, by G. H. Kinahan, M.R.I.A. Read by Mr Gibb.

3*d May* 1883.—On Calcareous Deposits at Starleyburn, Fifeshire, by John Henderson, *Councillor*.

9*th May* 1883.—Special General Meeting to consider the arrangements for the Fiftieth Anniversary Meeting.

EXCURSIONS, 1883.

16*th June*.—Kinghorn. *Leader*, Mr John Henderson.
23*rd June*.—Stirling. Joint Excursion with Glasgow Geological Society.
30*th June*.—Dunbar. *Leader*, Mr Henderson.
14*th July*.—Inchkeith. *Leader*, Mr Henderson.
3*d and* 4*th August*.—Banff. Joint Meeting of Northern Societies.

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ROLL

OF THE

EDINBURGH GEOLOGICAL SOCIETY.

(*Corrected to* 1*st November* 1883.)

I. HONORARY FELLOWS.

(*The number is limited by Law to Twelve.*)

His Grace THE DUKE OF ARGYLL, K.G., K.T., D.C.L., F.R.S., Inverary Castle, Argyllshire, and Argyll Lodge, Campden Hill, London. *Patron of the Society.**

JOACHIM BARRANDE, Corres. Mem. Imp. Acad., Vienna, 22 Rue de l'Odéon, Paris, and 419 Kleinseite, Choteksgasse, Prague.

Sir ANDREW CROMBIE RAMSAY, LL.D., F.R.S., F.G.S., 15 Cromwell Crescent, London, S.W.

THOMAS DAVIDSON, of Muirhouse, F.R.S., F.G.S., 9 Salisbury Road, West Brighton.

ARCHIBALD GEIKIE, LL.D., F.R.S., F.G.S., Director General of the Geological Survey of the United Kingdom, Jermyn Street, London, S.W. President of the Society, 1868-74.

JOHN HUTTON BALFOUR, M.A., M.D., F.R.S., 27 Inverleith Row.

THOMAS C. ARCHER, F.R.S.E., Director of the Museum of Science and Art, Chambers Street.

THOMAS B. JOHNSTON, F.R.S.E., F.S.A. Scot., of Messrs W. & A. K. Johnston, Geographical Publishers, Edina Works, Easter Road.

WILLIAM NELSON, of Messrs Thomas Nelson & Sons, Publishers, Hope Park, Crescent.

JAMES GEIKIE, LL.D., F.R.S., F.G.S., Professor of Geology in the University of Edinburgh.

* His Grace was elected Patron in 1875. The former Patrons were Sir Roderick Murchison and Sir Charles Lyell, who successively held the appointment until their death.

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II. ORDINARY FELLOWS.

Those Fellows who have compounded for their Annual Subscriptions by becoming "Life Members" are marked with an asterisk. The dates indicate when the Fellows were elected.)

Adams, William, (Royal Bank of Scotland), 15 Hope Park Terrace, *Treasurer* (1880).
*Archibald, John, Devonvale, Tillicoultry (1868).
Armstrong, William, Jun., M.E., Wingate, Co. Durham (1869).
*Balfour, Isaac Bayley, D.Sc., Edin., F.R.S.E., Professor of Botany in Glasgow University (1874).
Bell, Robert, Amondell, Midcalder; and 7 Eglinton Crescent (1866).
Bell, W. Hamilton, 6 Mansionhouse Road (1880).
Binning-Home, G. H. Munro, of Argaty, Doune, Stirling (1873).
Black, W., S.S.C., 3 Hill Street (1880).
Black, Dr W. G., 2 George Square (1873).
10*Blyth, Rev. Dr Thomas Allen, M.A., Ph.D., 84 James Street, Iffley Road, Oxford (1864).
*Bray, Henry Adam, M.D., Market Rasen, Lincolnshire (1878).
Bryce, A. Hamilton, LL.D., D.C.L., F.R.S.E., 42 Moray Place (1879).
Bryce, Wm., M.D., 31 Charlotte Square (1880).
Buchanan, John, C.E., 24 George Street (1868).
Cadell, Henry, of Grange, Bo'ness, 13 Douglas Crescent, (1866).
Cadell, Henry Moubray, B.Sc. Edin., Grange, Bo'ness; Geological Survey of Scotland; 13 Douglas Crescent (1880).
Calderwood, Robert, Oakbank Oil Co., Midcalder (1882).
*Cameron, David, Schoolhouse, Daviot, Inverness (1881).
Carey, William, Struan Villa, Portland Road, Kilmarnock (1866).
20 Carter, William Allan, C.E., 5 St Andrew Square, *Librarian* (1874).
Craig, George, architect, 85 Constitution Street, Leith (1882).
Conchie, William, Public School, Livingston, Mid-Calder (1876).
Coyne, Roderick A. F. A., C.E., Edinburgh and District Water Trust Offices, Royal Exchange (1864).
Dalzell, John Brown, Merchant, Lesmahagow (1866).
Daniell, Alfred, M.A., B.Sc., Lecturer on Medical Physics, School of Medicine, Chambers Street; and 40 Gillespie Crescent (1877).
*Deans, P. D., Mount Charles, Portobello (1876).
Douglas, Robert, Solicitor and Town-clerk, Berwick-on-Tweed (1874).
Drummond, William, S.S.C., 21 Charlotte Square (1868).
Farquharson, Rev. Alexander, 3 Abercrombie Street, Chesterfield, Derbyshire (1880).
30 Farquharson, Thos. Ker, Accountant, 15 St Catherine's Place, Grange (1875).
Ferguson, John, 15 Brighton Place, Portobello (1863).
*Ferguson, William, of Kinmundy, Mintlaw, Aberdeenshire, F.R.S.E., F.L.S., F.G.S., 41 Manor Place, and University Club, Princes Street, *Vice-President* (1876).
Field, W.m, 1 Hart Street (1864).
Fleming, Andrew, M.D., F.R.S.E., Deputy Surgeon General H.M. Indian Army, 8 Napier Road, Merchiston (1875).
*Fraser, Alexander, Canonmills Lodge (1869).
*Fraser, Charles, 13 Greenhill Place (1882).
*Fraser, James, C.E., 100 Castle Street, Inverness (1881).
Fraser, William, Manager, Oil Works, Broxburn (1882).
Galletly, John, Chemist, Addiewell, West Calder (1877).
40 Galloway, John, Barleith and Dollars' Collieries, Kilmarnock (1866).
Gibb, Philip B., M.A., 14 Picardy Pl., *Assistant Librarian* (1880).

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Gray, Archd., C.E., Glengarnock Ironworks, Glengarnock (1866).
Greenwood, Arthur, M.A., LL.D., F.R.S.L., Fell. Trin. Coll. Lond., Flaxfield College, Basingstoke, England (1879).
Greig, John, Coltness Iron Works, Wishaw (1865).
Guthrie, J. Young, S.S.C., 4 Rosebery Crescent; and 29 Hanover Street (1876).
Hanson, E. S., Paul's Work (1878).
Harrison, George, The Right Hon. The Lord Provost, 7 Whitehouse Terrace (1867).
Henderson, John, Curator Phrenological Museum, Chambers Street (1862).
Henderson, William, of Redford, Royal Bank, Leith (1873).
50*Hood, Archd., Coalmaster, Whitehill Colliery, Lasswade (1869).
Horsburgh, John, Photographer, 131 Princes Street (1863).
*Hunter, John R. S., LL.D., D.Sc., Daleville, Carluke (1862).
Jeffrey, David, 14 Randolph Crescent (1867).
Jenner, Charles, F.R.S.E., Easter Duddingstone Lodge, Portobello (1867).
*Jolly, William, F.R.S.E., H.M. Inspector of Schools; 25 St Andrew Drive, Pollockshields (1867).
*Kellock, Robert, Glendyne Cottage, Joppa (1881).
Ker, Robert Darling, 11 Moston Terrace (1863).
Kilgour, T. W., 4 East Brighton Crescent, Portobello (1874).
Kinnear, W. Tait, 5 Crichton Street (1881).
60*Knott, C. G., M.A., D.Sc., Professor of Natural Philosophy, Tokio College, Japan; 2 Lauriston Park (1883).
Landale, Andrew, Lochgelly Ironworks, Lochgelly, Fife (1864).
Landale, David, M.E., 10 St Andrew Square (1863).
Landale, James, M.E. (1868).
Lapworth, Chas., F.G.S., Professor of Geology, Sir Josiah Mason College, Birmingham (1869).
Lewis, James Henry, Mus. B., Organist, West Hartlepool (1882).
*Linford, William, Elstow, St James', Exeter (1873).
Linn, James, Geological Survey of Scotland, Moss Street, Keith (1868).
Livesay, William, M.D. Edin., Sudbury, Derby (1869).
Livingston, Josiah, 4 Minto Street (1867).
70*Lumsden, Alexander, M.E., Addiewell Oil Works, West Calder (1865).
*Macadam, W. Ivison, F.C.S., F.I.C., Lecturer on Chemistry, and Analytical Chemist, School of Medicine, Surgeon's Hall; Professor of Chemistry, New Veterinary College; 6 East Brighton Crescent, Portobello, *Honorary Secretary* (1878).
M'Diarmid, William R., F.S.A. Scot., 8 Palmerston Place (1877).
M'Ewan, William, 43 Manor Place (1878).
Macfie, R. A., F.R.S.E., Dreghorn Castle, Colinton (1878).
M'Raild, Donald, F.R.C.S.E., L.F.P.S.G., &c., 29 West Burn Street, Greenock (1882).
Mack, Anthony, J.P., 6 Crescent, Ardrossan (1873).
Mackay, Æneas, J.G., M.A., LL.B., Advocate, 7 Albyn Place (1867).
*Mackenzie, John F., C.E., H.M. India Service, 32 London Street (1873).
Maclachlan, D., Publisher, 64 South Bridge (1867).
80*M'Lagan, P., M.P., F.R.S.E., Clifton Hall, Ratho (1875).
M'Laren, Duncan, Newington House (1873).
*Marshall, W. H., of Callander, M.A., W.S., 25 Heriot Row (1875).
*Maughan, Edward, 119A George Street (1874).
Meik, Walter, C.E., 6 York Place (1881).
*Melven, William, M.A., 32 Gibson Street, Hillhead, Glasgow (1878).
*Melvin, James, 43 West Drumsheugh Gardens (1868).
Miller, George, Sharebroker, 60 Princes Street (1863).
Miller, Wm., Merchant, Bo'ness (1881).
*Milne-Home, David, of Milne-Graden, LL.D., *V.P.*R.S.E., F.G.S., Milne-Graden, Coldstream; and 10 York Place, *President* (1871).

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90 Moore, Ralph, Colliery Manager, Smeaton Park, Inveresk, Musselburgh (1878).
NORTHESK, The Right Hon. The EARL OF, Longwood House, near Winchester, Hants; and Ethie House, Forfarshire (1869).
Oliver, J. S., 12 Greenhill Park (1879).
*Omond, R. Traill, Ben Nevis Observatory, Fort-William; and 43 Charlotte Square (1881).
Ormiston, Archibald R., Shotts Ironworks, Shotts (1866).
*Panton, George A., F.R.S.E., Resident Secretary Scottish Provident Institution, 95 Colmore Row, Birmingham (1862).
Paterson, Robert, Architect, 47 Grange Road (1871).
Paul, Gavin, 14 Maitland Street (1866).
*Powrie, James of Reswallie, F.R.S.E., F.G.S., Reswallie, near Forfar (1867).
*Prentice, Thomas, Mining Manager, Addiewell, West Calder (1877).
100*Richardson, Ralph, W.S., F.R.S.E., 19 Castle Street and 10 Magdala Place; Newpark House, Mid-Calder, *Vice-President* (1866).
Riches, C. Maplestone, Northbury House, Bury St Edmunds (1880).
Ritchie, James, C.E., Perth (1867).
Robinson, E. C., Shaftesbury House, London Fields, E. (1882).
Robinson, John Ryley, LL.D., F.R.G.S., 47 Westgate, Dewsbury, England (1865).
Rodrigues, Antonio Cesar, 1 Castle Street (1880).
Rogers, Rev. Charles, D.D., LL.D., 16 Danube Street (1882).
*Romanis, Robert, D.Sc., Government Analyst, Maulmain, British Burmah (1876).
Romans John, C.E., 30 St Andrew Square (1867).
Rorie, G. L., Banker, 60 Union Street, Aberdeen (1868).
110*Semple, Andrew, M.D., &c., Honorary Deputy Surgeon-General H.M. Army Medical Service, United Service Club (1882).
Shiells, R. Thornton, Architect, 65A George Street (1867).
*Shipston, Thomas Wiseman, M.A., LL.D., Arlington House, West Ham, London, E. (1871).
Simpson, Alex. Gray, 2 Lauder Road (1865).
Simpson, George, 2 Lauder Road (1873).
Small, Robert, Sub-Inspector of Schools, 3 Bernard Terrace (1869).
Smith, Henry Murray, M.A., Collegiate School, Charlotte Square (1880).
*Smith, Robert M., F.R.S.E., 4 Bellevue Crescent (1867).
Smith, Frederick, 3 Malta Terrace, Stockbridge (1875).
*Spowart, Thomas, of Broomhead, Dunfermline; and 7 Coates Crescent (1863).
120 Sprague, T. B., M.A., F.R.S.E., 29 Buckingham Terrace (1878).
Steuart, Thomas Barker, Manager, Queensbury Silver Lead Mines, Wanlockhead (1882).
Stevenson, David, C.E., *V.-P.* R.S.E., 84 George Street (1875).
*Stevenson-Hamilton, Colonel Jas., of Fairholm, Larkhall, Lanarkshire (1865).
*Stewart, D. R., Chemist, Broxburn (1876).
Stock, Thomas, Museum of Science and Art, Chambers Street; 16 Colville Place (1879).
Stoddart, Mark P. (1878).
*Sturman, Edward A., M.A., Ph.D., 70 Seven Sisters' Road, Holloway, London, N. (1870).
*Sturrock, Peter, C.E., Kilmarnock (1866).
*Sutton, William, LL.D. (1871).
130 Tait, Adam, 11 Lutton Place (1881).
*Thin, James, Bookseller, 55 South Bridge (1867).
*Thomson, Robert, (1875).
Thomson, William, Public School, Whitburn (1879).
Tunny, James G., Photographer, 11 Salisbury Place (1862).
Turnbull, James, Printer, 14 Thistle Street (1867).
*Wallace, Thomas D., F.S.A., Scot., Rector of High School, Inverness (1879).

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Watts, Rev. G. J., M.A., LL.D., Vicar of St Marks, Oldham, Lancashire (1880).
Williamson, John R., M.E., 46 George Square (1869).
Wilson, Jas., *Border Record*, Galashiels (1873).
140* Wilson, Charles Monck, M.A., LL.D., F.R.D.S., C.E., Rose Villa, North Strand, Limerick, and Kildare Street Club, Dublin (1871).
Young, A., F.R.S.E., 22 Elm Row (1882).

III. ASSOCIATES.*

(*The dates indicate the year of election.*)

Rev. Henry W. Crosskey, F.G.S., 28 George Street, Edgbaston, Birmingham (1864).
Henry Murphy, Proprietor *Sheffield Post* Newspaper, 25 Howard Street, Sheffield (1864).
Nicholas Whitley, C.E., Penarth, Truro, Cornwall (1865).
Edward A. Wünsch, F.G.S., 88 St Vincent Street, Glasgow (1866).
John Young, F.G.S., Hunterian Museum, University of Glasgow (1867).
James Armstrong, 16 Albert Drive, Crosshill, Glasgow (1867)
Andrew Taylor, F.C.S., Mineral Surveyor, 37 South Clerk Street (1867).
Edward Hull, M.A., F.R.S., F.G.S., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science, Dublin, 14 Hume Street, Dublin (1869).
Rev. Robert Hunter, M.A., F.G.S., Forest Retreat, Staples Road, Loughton, Essex, London, W.C. (1869).
10 Henry Woodward, F.R.S., *C.*G.S., F.Z.S., British Museum, London, W.C. (1869).
Charles William Peach, A.L.S., 30 Haddington Place (1871).
Rev. Thomas Brown, F.R.S.E., 16 Carlton Street (1874).
Joseph Prestwich, M.A., F.R.S., *V.-P.*G.S., F.C.S., Professor of Geology in the University of Oxford, 35 St Giles Street, Oxford (1875).
Robert Brown, M.A., Ph.D., F.R.G.S., F.L.S., Fersler, Rydal Road, Streatham, London, S.W. (1875).
G. H. Kinahan, M.R.I.A., F.R.G.S.I., District Surveyor of the Geological Survey of Ireland, Lurgybrack, Letterkenny (1875).
John W. Judd, F.R.S., *Secy.* G.S., Professor of Geology, Royal School of Mines, Jermyn Street, London, S.W. (1875).
Frederick W. Rudler, F.G.S., Professor of Natural History in the University College of Wales, Aberystwith; Museum of Practical Geology, Jermyn Street, London (1875).
Alexander Croall, Curator of the Smith Institute, Stirling (1875).
D'Arcy Wentworth Thompson, 27 Alva Street (1881).
20 Alexander Somervail, 59 Fleet Street, Torquay (1881).

* Law XVI. enacts, "The Society shall have power to elect by ballot, as *Associates*, gentlemen distinguished for their Scientific attainments and researches, particularly in any department of Geology, or who may have acquired claims on the Society by aiding the furtherance of its objects."

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IV. FOREIGN CORRESPONDING FELLOWS.

(The dates signify when elected.)

I. Europe.

1. *Switzerland.*

Dr Ferdinand Keller, Zurich (1864).

Professor Alphonse Favre, For. Mem. G.S., Geneva (1869).

Rev. Dr Oswald Heer, For. Mem. G.S., Professor of Botany in the University of Zurich (1869).

Bernard Studer, For. Mem. G.S., Professor of Geology, Berne (1869).

3. *Norway.*

Dr Théodor Kjerulf, For. Mem. G.S., University of Christiania (1869).

4. *Sweden.*

M. S. Lovén, For. Corr. G.S., Stockholm (1869).

Professor Svend Nilsson, For. Mem. G.S., Lund, Sweden (1869).

Professor Otto Torell, For. Corr. G.S., Director Geological Survey of Sweden, Lund (1869).

5. *France.*

Paul Gervais, For. Mem. G.S., Professor of Comparative Anatomy in the Museum of Natural History, 11 Rue Rollin, Paris (1869).

10 Achille Delesse, For. Mem. G.S., Ingénieure en chef des Mines, 59 Rue Madame, Paris (1875).

6. *Germany.*

Professor F. Zirkel, For. Corr. G.S., 15 Thalstrasse, Leipzig (1869).

Hanns Bruno Geinetz, Ph.D., For. Mem. G.S., Professor of Mineralogy and Geology in the University of Dresden (1869).

Professor Fridolin Sandberger, Ph.D., For. Mem. G.S., Professor of Mineralogy, University of Würzburg, Bavaria (1869).

7. *Russia.*

General G. von Helmersen, For. Mem. G.S., St Petersburg (1869).

M. Von Kokscharow, For. Corr. G.S., St Petersburg (1869).

8. *Italy.*

G. Meneghini, For. Corr. G.S., Professor of Palæontology, University of Pisa (1869).

Paolo Savi, Professor of Zoology University of Pisa (1869).

B. Gastaldi, For. Mem. G.S., Professor of Geology, Turin (1869).

9. *Denmark.*

Johannes Frederik Johnstrup, Professor of Mineralogy, Copenhagen (1869).

20 Christian Georg Frederick Pfaff, Kong. Grönlandske Handel, Copenhagen (1869).

Professor Japetus Sm. Steenstrup, For. Cor. G.S., University of Copenhagen, Secretary of the Royal Danish Academy of Science and Literature (1869).

10. *Belgium.*

Laurent-Guillaume de Koninck, M.D., For. Mem G.S., Professor of Chemistry and Palæontology in the University of Liége (1869).

Professor A. Renard, Curator of the Royal Museum, Brussels (1878).

E. Grossart, 26 Rue de la Madeleine, Bruxelles (1881).

11. *Austria.*

Antonio Fritsch, Professor, Prague (1881).

II. Asia.

India.

Thomas Oldham, M.A., LL.D., F.R.S., F.G.S., Director of the Geological Survey of India, 1 Hastings Street, Calcutta (1864).

J. W. Johnstone, M.D., H.M. Bengal Army (1869).

III. Africa.

Charles Bell, Surveyor-General for Cape Colony, Belton, Somerset, Road, Cape Town (1864).

Dr George Grey, Cradock, South Africa (1864).

30 Dr Daniel Hahn, Stellenbosch, Cape of Good Hope (1875).

IV. America.

1. *Canada.*

George Lawson, LL.D., Professor of Chemistry in Dalhousie College, Halifax, Nova Scotia (1863).

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John William Dawson, LL.D., F.R.S., F.G.S., Principal of M'Gill's College, Montreal (1866).

2. *United States.*

Dr Daniels, State Geologist of Wisconsin, Madison, Wis. (1864).
Professor Alexander Winchel, State Geologist of Michigan, Professor of Geology and Palæontology, University of Michigan; Ann Arbor, Michigan (1864).
Professsr J. D. Whitney, For. Corr. G.S., State Geologist of California, Cambridge, Mass. (1866).
Professor J. H. M'Chesney, Chicago (1866).
Professor William P. Blake, of the State Department, Newhaven, Connecticut (1866).
William Gabb, Palæontologist of the Geological Survey of California (1866).
Professor Benjamin Silliman, Editor of "The American Journal of Science and Arts," Newhaven, Connecticut (1867).
40 Major T. B. Brooks, Wisconsin Geological Survey, Marquette, Michigan (1876).
Dr F. V. Hayden, For. Corr. G.S., United States Geologist, Washington (1877).

3. *Vancouver Island.*

John J. Landale, C.E., Victoria (1866).
George H. Wilson Brown, Victoria (1867).

V. Australasia.

1. *New Zealand.*

Julius von Haast, Ph.D. F.R.S., F.L.S., F.G.S., Director of the Canterbury Museum, Christchurch, Canterbury (1863).
James Hector, M.D., F.R.S., F.G.S., Director of the Geological Survey of New Zealand, Wellington (1864).

2. *Victoria.*

Frederick M'Coy, F.G.S., Professor of Natural History in the University of Melbourne, and Director of the National Museum, Melbourne (1866).

3. *Queensland.*

R. L. Jack, F.G.S., F.R.G.S. Government Geologist for Northern Queensland, Townsville (1878).

VI. Foreign Corresponding Fellows presently in Britain.

Peter Comrie, Staff Surgeon, R.N., Crichton Club, Adelphi, London, W.C. (1866).
Frederick Whymper, 170 Loughborough Road, Brixton, London, S.E. (1866).
50 Henry S. Wilson, M.D. (1863).
Edward M'Glashan, Castle Lodge, Sandal, Wakefield (1863).
James Coutts Crawford, of Overtoun (Lanarkshire), F.G.S., Resident Magistrate and Sheriff of Wellington (1863), Caledonian Club, Edinburgh; Reform Club, London.

V. LEARNED SOCIETIES AND INSTITUTIONS IN CORRESPONDENCE WITH THE SOCIETY.

I. Scotland.

Edinburgh.

*Royal Society.
*Society of Antiquaries of Scotland.
*Botanical Society.
Scottish Meteorological Society.
*Royal Physical Society.
Advocates' Library.
Signet Library.
University Library.
Highland and Agricultural Society of Scotland.
10 Scottish Chamber of Agriculture.
Philosophical Institution.
Literary Institute.

* This mark is placed opposite the names of Societies or Institutions from which the Edinburgh Geological Society received donations of Transactions, Proceedings, Memoirs, or Reports during 1882, and till the month of August 1883. To all such Societies and Institutions a copy of Part III. of Vol. IV. of the Society's *Transactions* (1883) has been sent free of charge.

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Glasgow.
*Geological Society.
*Natural History Society.
*Philosophical Society.
Athenæum.

Berwickshire.
*Naturalists' Club.

Perth.
*Perthshire Natural History Soc.

Dumfries.
*Dumfries and Galloway Natural History and Antiquarian Soc.

II. ENGLAND.

London.
20 *Royal Society.
*Geological Society.
*Geologists' Association.
*Royal Geographical Society.
Zoological Society.
British Museum.
*Palæontographical Society.
*Linnean Society.
British Association.

Oxford.
Bodleian Library.

Cambridge.
30 University Library.

Manchester.
*Geological Society.
*Literary and Philosophical Soc.
*Scientific Students' Association.

Liverpool.
*Geological Society.
*Geological Association.
*Literary and Philosophical Soc.

Leeds.
*Geological Association.
Naturalists' Club.
*Philosophical and Literary Soc.

Norwich.
40 *Geological Society.
*Norfolk and Norwich Naturalists' Society.

York.
*Yorkshire Philosophical Society.
*Yorkshire Geological and Polytechnic Society.

Birmingham.
*Mason College.
*Philosophical Society.

Bristol.
*Naturalists' Society.

Truro.
*Royal Institution of Cornwall.

Penzance.
*Royal Geological Society of Cornwall.

Warwick.
Warwickshire Natural History Society.

Newcastle-on-Tyne.
50 Literary and Philosophical Soc.
*Northumberland and Durham Natural History Society.
*Tyneside Naturalists' Field Club.

Watford, Hertfordshire.
*Natural History Society.

Brighton.
*Natural History Society.

Buckhurst Hill (Essex).
*Epping Forest and County of Essex Field Club.

Eastbourne.
*Natural History Society.

III. IRELAND.

Dublin.
Library of Trinity College.
*Royal Irish Academy.
*Royal Geological Society of Ireland.
60 Institution of Civil Engineers.
*Royal Society.

Belfast.
*Naturalists' Field Club.

IV. FRANCE.

Paris.
*Royal Academy of Sciences.
*Geological Society of France.
School of Mines.
Geographical Society.
*Department for Public Instruction.

Lyons.
*Société d'Etudes Scientifiques.
*Société Linnéenne de Lyon.

Amiens.
70 *Société Linnèenne du Nord.

Lille.
*Société Geologique du Nord.

V. BELGIUM.

Brussels.
*Royal Academy of Sciences.
*Department of Mines.
*Musée Royal d'Histoire Naturelle de la Belgique.
*Carte Geologique de la Belgique.

Liége.
*Royal Society of Sciences.
*Société Geologique de la Belgique.

VI. SWITZERLAND.

Geneva.
Société de Physique et d'Histoire Naturelle.

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Lausanne.
*Société Vaudoise de Sciences.
Zürich.
80 Naturforschende Gesellschaft.

VII. ITALY.

Rome.
*R. Com. Geologico d'Italia.
*Reale Accademie dei Lincei.
Florence.
*Royal Geological Society of Italy.
Turin.
Royal Academy of Sciences.
Venice.
*Royal Venetian Institute of Sciences.
Pisa.
*Societa Toscana di Scienze Naturali.

VIII. AUSTRIA.

Vienna.
*K. K. Akademie der Wissenschaften.
*K. K. Geologische Reichsanstalt.
K. K. Geographische Gesellschaft.
90*K. K. Zoologisch-Botanische Gesellschaft.
Buda Pest.
*National Museum of Hungary.
Trieste.
Societa Adriatica di Scienze Naturali.
Brünn.
*Naturforschenden Verein.
Innsbruck.
*Naturwissenschaftliche - Medizinischen Verein.

IX. BAVARIA.

Munich.
*K. b. Akademie der Wissenschaften.

X. BADEN.

Heidelberg.
*Naturhistorisch - Medicinischer Verein.

XI. SAXONY.

Dresden.
Naturwissenschaftliche Gesellschaft "Isis."
*Verein für Erkunde.
Leipzig.
Kön. Gesellschaft der Wissenschaften.
Braunsweig.
100*Naturwissenschaft Verein.

Wurtemberg.
Tübingen.
*Verein für Vaterlandishe Naturkunde.

XII. PRUSSIA.

Halle.
*K. Leopoldinisch - Carolinische Deutische Akademie des Naturforscher.
Berlin.
König. Akademie der Wissenschaften.
Königsberg.
*Physikalisch-Okonomische Gesellschaft.
Bremen.
*Naturwissenschaftlichen Vereins.

XIII. DENMARK.

Copenhagen.
*Royal Danish Academy.
*Royal University.

XIV. NORWAY.

Christiania.
Royal University.
*Norwegian North Atlantic Expedition.
Bergen.
110*Library of the Museum.
Troms.
*Troms Museum.
Trondhjem.
*Royal Scientific Society of Norway.

XV. SWEDEN.

Stockholm.
*Royal Academy of Sciences.
Upsala.
*Royal Society of Sciences.
Lund.
*Library of the University.

XVI. RUSSIA.

St Petersburg.
Imperial Academy of Sciences.
Imperial Geological Society.
Moscow.
Imperial Society of Naturalists.

XVII. CANADA.

Montreal.
*Geological Survey of Canada.
120*Natural History Society.

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Toronto.
*Canadian Institute.
Winnipeg (Manitoba).
*Historical and Scientific Society.

XVIII. United States.

New York.
*State Library, Museum and Cabinet of Natural History.
*American Geographical Society, No. 11 West 29th Street.
American Bureau of Mines.
American Ethnological Society.
*School of Mines, Columbia College.
*Academy of Sciences.
Washington.
*Smithsonian Institution.
130 United States Coast Survey.
*National Academy of Sciences.
*United States Geological Survey.
United States Department of Agriculture.
*Treasury Department.
*Bureau of Education.
Boston.
*Society of Natural History.
Public Library of the City.
Portland (Maine).
Natural History Society.
Cambridge (Mass.).
Library of Harvard College.
Salem (Mass.).
140*Peabody Academy of Science.
New Haven (Conn.).
*Connecticut Academy of Arts and Sciences.
Library of Yale College.
*American Journal of Science and Arts.
Philadelphia.
*Academy of Natural Sciences.
Chicago.
Academy of Sciences.
Bloomington (Ill.)
Natural History Society.
New Orleans.
Academy of Sciences.
San Francisco.
*California Academy of Natural Sciences.
St Louis.
*Academy of Sciences.
Cincinnati.
150*Society of Natural History.
Frankfort (Kentucky).
*Geological Survey of Kentucky.
Beloit (Wisconsin).
*Geological Survey of Wisconsin.
Minneapolis (Minn.).
*Geological and Natural History Survey.
Montana.
*Geological Survey.
Indiana.
*Geological Survey.

XIX. Nova Scotia.

Halifax.
*Nova Scotian Institute of Natural Science.

XX. Australia.

Melbourne.
National Museum.
Royal Society of Victoria.
*Government Office of Mines.
160*Geological Survey,
Brisbane.
*Government Office of Mines.
Sydney.
*Royal Society of New South Wales.
*Government Office of Mines.
Townsville.
*Geological Survey.
North Queensland.
*Geological Survey.

XXI. New Zealand.

Wellington.
*New Zealand Institute.
*Colonial Museum.
*Department of Mines.
Dunedin.
Otago Institute.

XXII. Brazil.

Rio de Janeiro.
170 Commissao Geologica do Imperio do Brazil.
*National Museum of Rio de Janeiro.

XXIII. Mexico.

Mexico.
*Geographical Society.

Society's Library—5 St Andrew Square.

**** The Members of the Society are requested to intimate to the Honorary Secretary, Surgeons' Hall, all changes of residence.*

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